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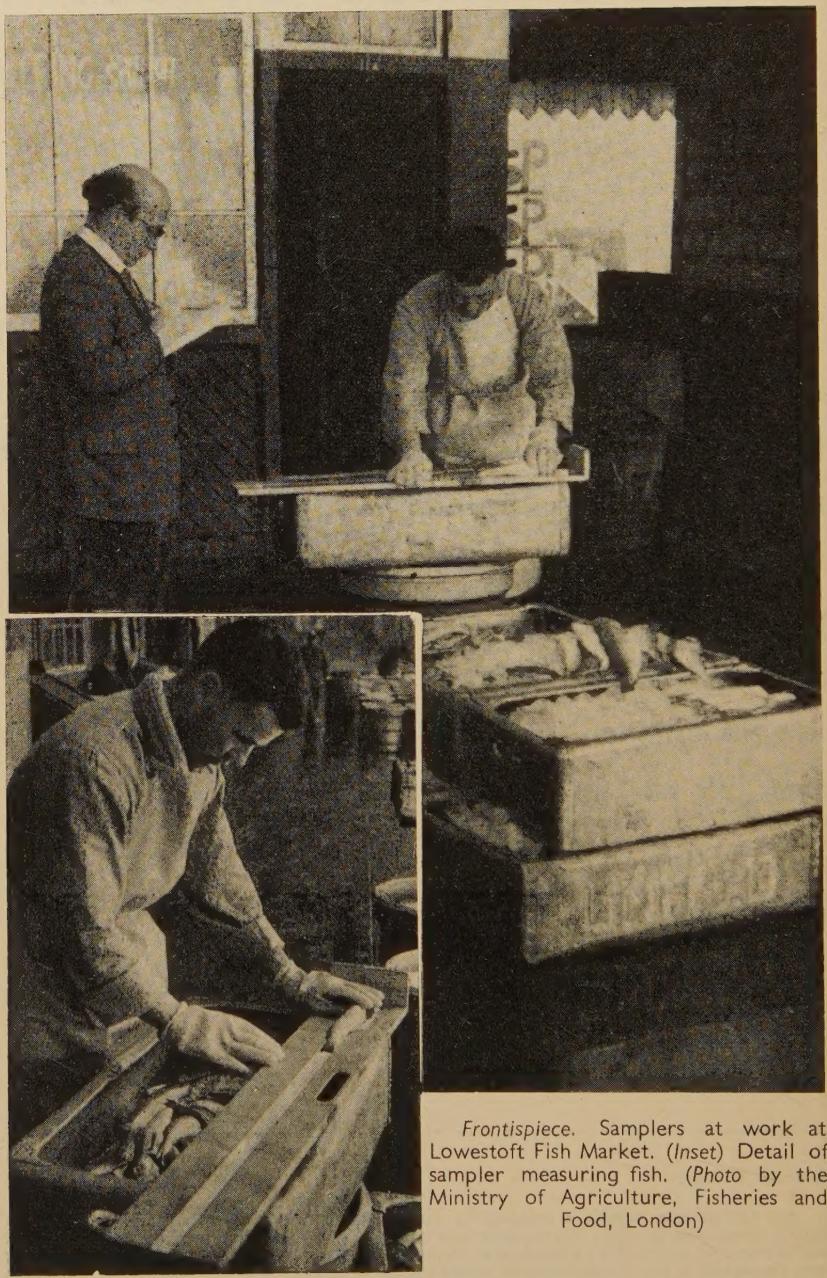

Frontispiece. Samplers at work at Lowestoft Fish Market. (*Inset*) Detail of sampler measuring fish. (*Photo* by the Ministry of Agriculture, Fisheries and Food, London)

SAMPLING PROBLEMS AND METHODS IN FISHERIES RESEARCH[1]

(A simple introduction to the principles of tackling sampling problems as they arise in fish population studies, particularly with regard to the catches of commercial vessels, and their size and age compositions. Some other problems likely to be met in fisheries biological studies will be touched on, but the principles discussed below are generally applicable.

Mr. Gulland is now preparing for FAO a manual containing details of the statistical procedures with worked examples for the use of biologists concerned with sampling problems).

Introduction

A common problem for the fishery scientist is to measure some attribute of a population, such as the average density of diatoms in some area of the sea, or the percentage of mature fish in a catch. It is often difficult or impossible to examine the whole population; all the diatoms in the sea cannot be counted, and examining all the fish in the catch for maturity may take an inconveniently long time.

A part or sample of the whole population is then taken and examined for the attributes concerned as by filtering a certain known volume of water by means of a plankton net haul and counting the number of diatoms. On the assumption that this sample is in some way representative of the whole population, an estimate can be made of the true value in the population. The purpose of a good sampling system is to obtain an estimate of required accuracy with the least possible effort as in terms of money, time, staff, and so on. Thus, the design of a suitable sampling procedure, and the subsequent methods of analysis, should be a matter of direct concern to fishery biologists, and, in fact, sampling problems have recently been among the subjects of particular attention at meetings of both the International Commission for the Exploration of the Sea (ICES) and the International Commission for the Northwest Atlantic Fisheries (ICNAF).

Although in general sampling systems are employed when it is impracticable to obtain complete information (e.g., on the sizes of all fish landed), a sample would not necessarily be less useful than a complete census. Even in cases where it might be possible to get complete information, the data obtained from a good sample is often much more accurate and more reliable than that from a complete, but in some other respect deficient, census. For instance, data on total catches may be obtained from information used also for tax purposes, for which the reported catch may well be considerably less than the real catch. An estimate of total catch made from an

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[1]by John Gulland, Fisheries Laboratory, Lowestoft, England.

independent sample could be more reliable than the reported total catch.

Sampling problems are a constant feature of fishery research. The intensity of sampling may vary from that of a simple plankton net haul, perhaps being only one thousand millionth of the total population, to a sub-example of the catch of a research vessel, which may be half or more of the total catch. It should be noted that a sample is not necessarily a small portion of the total population. Again, the observations as actually made may be the result of a series of successive, more or less complicated, sampling procedures.

The first step in a sampling system is to delimit the scope of the system. A biological investigation is often concerned with a self-contained population of organisms ; this term " population " is also used by statisticians in a similar sense to denote the collection of objects in which they are interested, and from which the sample is drawn. The two usages are often not distinct, but the statistical usage is wider, embracing any collection of objects or measurements, e.g., the cod in the North Sea form a population, but in the statistical sense so may the cod in a particular trawl haul and, if their lengths are of interest, then the set of the lengths forms a " population. " Once the population to be sampled has been defined, the next step is to define the quantity, or quantities, in the population, for which estimates are to be made, such as the percentage of mature fish, or the average weight of a certain kind of food in the stomachs. Next, the precision with which the estimates are required, must be decided. It is then possible to design a sampling system which will be good, or the best for that purpose.

I. Variance and Bias

The success, or otherwise, of a sampling system, depends on the consistency of the results it gives. In all but exceptional cases, the estimate obtained will not be exactly equal to the " true value " in the population ; the exact difference for any particular sample will depend to some extent on chance. If the sampling method is a good one, most of the estimates obtained from a series of separate samples will be close to the " true " value (and, perhaps more important, to each other), some very close, but a few unlucky samples, will give estimates differing more widely. A poor method of sampling may also, on occasions, give an estimate very near to the true value. Therefore, the estimate from a single sample gives, in itself, no clue to the suitability of the sampling method, thus more interest is shown in the distribution of estimates which would be obtained by a large number of repeated samples. The essential features of this distribution can be described by two quantities. First, the center of distribution may not coincide with the true value, e.g., most estimates being greater than the true value. The amount of this difference, between the true value and the average

value of a large number of estimates, is called the *bias*. (The term " bias " is also used for the process whereby the difference arises). Secondly, the estimates will be scattered about their mean value (which may or may not be the true value, depending on the existence of bias), and the amount of this scatter is the *variance*, which is the average of the square of the differences of the individual estimates from their mean. If the estimates are widely scattered, the variance will be large ; if they are all much the same, it is small. It should be noted that the variance is itself an estimate of a " true " variance ; repeated estimates will be scattered about a central value which may or may not be biased, and the degree of scatter will be measured by their variance.

Bias and variance refer not to an estimate from a single sample, but to a general distribution which would be obtained as a result of repeated samples. Thus, a method may have a large positive bias, but (particularly if the variance is large), the estimate obtained from a sample might be below the " true " value, even though most estimates would be above this value. Again, one estimate might be almost exactly equal to the true value, even when the variance is very large — but most estimates will differ very greatly.

Bias may arise from a poor method of analysis, but more often from a poor choice of samples, or from the method by which the measurements or counts are made or the samples obtained (e.g., if the fish are sorted when landed, and samples are mainly taken from the larger categories, the average size will be overestimated — a postitive bias in mean size — or if the hauls are made with a coarse meshed net the numbers of small diatoms will be underestimated — a negative bias in mean numbers of small diatoms, but a positive bias in mean diatom size). Some form of bias often occurs particularly when attempting to obtain samples typical of the true conditions in the sea, whether of diatoms with a plankton net, or of fish with a trawl.

Because bias, when it exists, affects all samples equally, it cannot be removed or reduced by increasing the amount of sampling ; the bias of the mean of a number of samples is the same as that of any one sample. Also the bias cannot be detected in subsequent analysis by comparing different samples, but only by detailed examination of the original sampling procedure.[2]

A word may be said here about the properties of the variance. It is a convenient method of expressing the scatter of estimates about a central value because in squaring the deviations of each value from the average value, no attention need be paid as to whether a particular estimate is a certain amount less or greater

[2]Some sources of bias, and their amount, may be readily determinable from the characteristics of the sampling process, and it may be more convenient to allow them to occur, correction for the bias of known extent being made in the later analysis. More often the existence, and more particularly the amount, of bias is not easily determined, and the possible sources of bias have to be thoroughly investigated and as far as possible eliminated before sampling. In either case, the bias has to be considered before sampling, and not merely in subsequent analysis.

than the average, because the square of a negative quantity is positive. The variance has also other advantages in algebraic manipulation. However, because of the fact that squares of differences are summed, it is rather sensitive to large discrepancies — arriving perhaps through one aberrant or erroneously recorded observation, and sometimes, for this and other reasons, other measures of scatter are more appropriate.

The square root of the variance is termed the *standard deviation,* and is often used in demonstrating the precision of estimates obtained from a sample. If these estimates are distributed in a certain manner, called the normal distribution, then 95% will differ from the mean value by less than twice the standard deviation. Since in practice the value of the mean is unknown, this fact is taken as meaning that, 95% of the time, the value of the mean is within twice the standard deviation of the estimate obtained. For instance, from a series of samples taken to estimate the total catch, the estimate obtained was 550 tons, and the standard deviation 35 tons. Then there is only a 5% chance that the actual total catch was outside the limits 550 ± 70, i.e., less than 480 tons or more than 620 tons. These limits are called the 5% *confidence limits*, and it is of course possible to calculate confidence limits for any other order of precision — 1% and 2% limits are commonly used.

Confidence limits are quite arbitrarily defined ; they represent the order of probability upon which it has been found convenient, in practice, to base decisions and take specified action. The kind of practical situation in which the idea of the confidence limit has unconsciously been applied, is in the decision of most motorists to carry one spare tire, and one only — a choice based on the fact that in normal traveling a single puncture is quite a likely occurrence, but two in a time interval so short that a repair could not conveniently be made within the interval, is very unlikely. The latter probability is increased greatly if long journeys are to be made over bad roads, and then the decision may be to carry two spares. Measurements of the frequencies of punctures could be made which would permit setting limits of confidence for these alternative decisions, but no final rule could be set down ; only the relative inconveniences can be weighed of carrying an extra wheel as against risking a certain probability of breakdown.

The variance is of major theoretical importance. For instance, the variance of the sum of two quantities is the sum of the variances of each quantity considered separately, i.e., when estimates of some quantity are obtained as the result of the combination of two or more quantities, each having a certain variance, then the variance of the final estimates is obtained from the appropriate combination of the original variances.

Another and perhaps more important property of the variance is that, under constant conditions, the variance of the estimate obtained from some sampling system will be inversely proportional to the size of the sample taken. Therefore, increased sampling re-

sults in a decrease in the variance. Because the variance is a squared quantity, this relation of inverse proportionality means that the error of estimation is decreased less than proportionately by a certain increase in sampling. In a single case it may be considered that a sample size of ten gives a certain precision of estimation : to double the precision a sample size not of 20 but of 40 is needed. This has an important bearing on the choice of the amount of sampling. When the size of sample is not restricted for other reasons, it will be chosen by balancing the cost of taking the sample against the losses likely to arise through errors in the final estimate. The probable size of these errors is given by the variance of the estimate, and this may — e.g., in some agricultural research — be expressible in definite monetary units which, balanced against the costs of sampling, determine a unique, economically best size of sample. In most fisheries work the effect of errors cannot, as yet, be expressed in such concrete terms, and, in fact, the possible size of sample is often restricted by practical reasons to a size well below such an economic optimum level.

However, two limiting sizes to the sample can be given with a knowledge of the variance. Firstly, below a certain size the estimate will be so inaccurate as to be of no value — the size of the sample must be increased, or the sampling procedure abandoned ; secondly, at a certain size the estimate will be accurate enough for all likely purposes, and to take larger samples would be a waste of effort. This latter situation occurs most often when the result of sampling has to be compared or combined with some other quantity subject to considerable variation, and there is little advantage in reducing the variance of the first quantity much below that of the second. To make these decisions, the sampling variance should be reasonably well-known. Usually in fisheries work the accuracy of sampling lies between these two limits. How, then, can the sampling effort available (money, time of staff, etc.) be used in the best possible way ? As shown above, the best method depends on the bias and variance of the estimates obtained. Normally, all bias should be eliminated, and the variance be as small as possible. When, however, the differences in some quantity, say from year to year, are of particular interest (rather than the absolute value of a quantity), a small and constant degree of bias may be acceptable.

II. Random Sampling

Probably no term in statistics has been more abused than the term *random sample*. It is often applied to samples obtained under conditions ranging from a strict randomizing procedure, which may involve using tables of random numbers, to picking merely the handiest numbers. A sample of objects from a population is random if all objects in the population have an equal chance of appearing in the sample. It is very important to remember that this applies to all objects in the group, to exceptional as

well as typical members. For instance, the whiting landed by any one ship at Lowestoft will usually (and for this example it is assumed always) have a smooth unimodal length-composition, with the mode usually between 28 to 30 cm., but occasionally (say once in 30 times) as high as 35 cm. A single random sample of whiting, taken from one ship, must, therefore, occasionally (once in 30 times on average) give a mode at or above 35, but usually at 28 to 30 cm. (The " population " here is the modal lengths of each catch of vessels landing at Lowestoft). If then a fishery biologist, relying on a sample from one ship only, obtained a mode at 35 cm., there has not necessarily been non-randomness because such misfortune will occur once in 30 times. The answer is to take more samples, sufficient to make negligible the chances that all or most fish have come from exceptional ships, i.e., to reduce the variance in the estimated average value of the mode to a conveniently small amount.

Another type of sample may be termed the *selected sample* (or *judgment sample*, as by Deming [1]). This is a sample considered by the investigator to be typical of the population sampled. Thus, a fishery biologist, arriving at Lowestoft market to measure a single sample of whiting, might readily discover by enquiring, which particular landing of whiting corresponded with the usual size of whiting at the port, and then measure those. Such a sample would be fairly certain to give a mode around 28 to 30 cm. Thus, if only one sample is taken, and all that is required is a general idea of the population sampled (e.g., is the mode in the length of whiting at Lowestoft around 25, 30 or 35 cm. ?) a selected sample has its merits. But samples taken in this way cannot be used with confidence for any statistical analysis. For example, a series of proper random samples enables the variance to be calculated, and hence confidence limits assigned with which the true value must lie, with a known degree of probability. Corresponding *typical samples* may all give values much the same, but these values may not even be close to the true value, and there is no way of determining, from the samples, how near or far the true value is likely to be. If the sampler considered that in the whiting landings a mode at about 31 cm. is typical, all the samples taken may have modes about 31 cm., and there will be nothing to indicate that truly the average mode is around 29 cm., nor will the error be reduced by taking more samples.

Therefore, while in some circumstances non-random samples may be useful, proper random samples are almost always preferable, and are virtually essential in a regular sampling routine. This, of course, refers to the primary sampling procedure ; as will be described below, the complete sampling pattern may be composed through stratified, or multi-stage sampling, of a number of such primary random samples, and so will not be entirely random.

A useful, and widely applicable, method of obtaining a truly random sample is by means of *random numbers*, as described in

most statistical textbooks. The population to be sampled is numbered and the units to be sampled are determined by reference to a table of random numbers. For instance, to draw a sample of 5 from a population of 100, the table given by Fisher and Yates (2) may be consulted. The first row of the table is 3, 47, 43, 73 and 86, and the 5 units corresponding to these numbers form the sample.

Instead of choosing all the units in the sample individually from the table of random numbers, units may be taken at regular intervals, e.g., every fifth or hundredth unit, and only the first chosen by use of random numbers. In the example, one twentieth of the population is to be sampled, so that the sampling interval would be 20, and the five units in the sample would then be 3, 23, 43, 63, and 83. Such a system can be dangerous when there is any natural periodicity in the population corresponding to the interval of sampling. For example, sampling at a port every seventh day to obtain total catch is likely to give very misleading results when there are great systematic differences between landings on different days of the week.

If a method, using random numbers or some other randomizing device, is impossible, no great harm is done so long as there is no relation between the quantity being measured and the probability of its occurrence in a sample. At Lowestoft market the choice of ship from which length measurements are to be made is not predetermined, but is made " at random " when the team of measurers arrives (a proper pre-determined random choice of ship would be complicated but not impossible, because the number of ships landing would not be known until the time of sampling). In fact, the choice is not entirely random because landings nearer to the entrance to the market and, in winter, away from the coldest and most exposed corners, are more likely to be sampled. There is, however, little reason to suppose that there is any correlation between the size of the fish caught and the position of the ship on the market, the latter being determined by the order of arrival after eight to twelve days at sea. It is, therefore, not unreasonable to assume that a slight non-randomness in choice of ship carries no bias. Care should be taken in making such assumptions ; if the ships returned to harbor each day, such a correlation could well occur, each factor being related to the grounds fished and distance from port. If then, for example, the more distant grounds had bigger fish, but the later arrivals, mainly from these grounds, were less likely to be sampled being in the further part of the market, a bias would be introduced, the average size of fish being underestimated. If at all possible, the assumption such as that there is no correlation between size of fish and position on the market, should be tested by direct observation. For instance, in the Lowestoft sampling program, after the ship for sampling has been chosen, a further choice has to be made of the particular box of fish to be measured. Here the choice is definitely not random, as the boxes

are arranged in blocks, only those at the end of the blocks being readily accessible for measuring. The end boxes are also the first (or last) landed, and thus nearly the last (or first) caught, and may well not be typical for the whole catch. Such a sampling system cannot be considered satisfactory without further investigation. However, a special sampling survey in which several boxes from different parts of the landing of the same ship were measured, showed that the difference in size of fish, if any, was not sufficiently great to introduce important errors, and hence, for sampling of length, the non-random choice of box was acceptable. If, however, the sampling was made in order to determine the freshness of the fish, samples from different parts of the landing might give very different results showing that a more truly random sample was necessary.

When testing whether a difference such as that between the average sizes of fish in different parts of the catch is significant, the distinction between statistical significance (as given by one of the standard statistical tests), and the practical or biological significance, must be clearly maintained. The practical test is whether the difference is so small that the error introduced by considering the two parts to be the same can be neglected. The usual statistical test gives the probability with which the observed difference or greater would occur if there were no real difference ; if this is less than 0.05, then the difference is said to be significant at the 5% level. The two approaches are best illustrated by examples. Suppose two small samples differing in average length by 2 cm. are taken from two parts of the landings, and that the standard deviation of the difference was 1.5 cm., then the statistical t-test gives a value of $t = 1.33$, and a probability of about 0.2, which is not significant. However, a real difference of 2 cm. in average length may be large enough to be of great practical significance, and before assuming the two parts of the catch were the same, additional samples should be taken to determine the difference more accurately.

Conversely, two very large samples may be taken, with average lengths differing by only 0.2 cm., but, due to the increased size of sample, the standard deviation has been reduced to 0.08 cm. Now the value of $t=2.5$, with a probability of about 0.01. Therefore, the difference is statistically significant at the 1% level. However, in practice a difference of 0.2 cm. may not be important, and no appreciable error would be introduced by treating the two parts as the same.

III. Sub-sampling and Stratified Sampling

The sampling of Lowestoft trawler landings for length composition is a good example of multi-stage sampling (or sub-sampling). In such a system, instead of choosing the units to be sampled (in this case, boxes of fish to be measured) from the whole population (the total landing) directly, the population is divided first into pri-

mary units (the landings by individual boats), and a sample of these primary units chosen. For the second stage, a second sample (or sub-sample) is taken from this primary sample (a box, or boxes, of fish chosen from the ship's landings). A third, or even further, stage of sampling can be used, as practised at Lowestoft where, at least for some species, only a sample of fish from the box (perhaps half) is measured. Such a system has many practical advantages, for sampling from within a fairly compact primary unit is likely to be much easier than taking a sample from the whole population. For example, measuring a couple of hundred fish chosen entirely at random from the landings of half a dozen trawlers would be an immense task. Again in plankton work, especially on phytoplankton or small zooplankton, the original sample as taken by the net may be so large that only by taking a sub-sample can the data be handled. The mathematical steps needed in analyzing a two-stage sampling system may be illustrated by showing the calculations needed to estimate the number of whiting of say 30 cm. length landed in a month. In all, say 60 ships landed ; from these a primary sample of six ships was taken. In the second stage of sampling one box of fish was sampled from among the 8 boxes of whiting landed by the first of the sampled ships. This contained 20 fish of 30 cm. Thus, this ship landed an estimated $20 \times 8 = 160$ fish of 30 cm. Similarly, the numbers landed by the other five ships sampled may be estimated and summing gives the number landed by the six ships as, say, 1,300. The number landed by all 60 ships may then be estimated at once to be $1{,}300 \times 60/6 = 13{,}000$ or, more accurately, if it is known that the six sampled ships landed 160 boxes, and that the total landings were 1,760 boxes, the estimate would be $1{,}300 \times 1{,}760/160 = 14{,}300$ fish.

Within the general pattern of two-stage sampling, a wide range of actual sampling procedures is possible, from taking a small number of primary samples and correspondingly large sub-samples (in the Lowestoft market example this would mean measuring a large number of fish from a small number of ships) to taking small sub-samples from a large number of primary samples, and the variance of the estimate obtained depends, often critically, on a suitable choice of sampling design. For a given cost of sampling (either financial cost, or cost in terms of time), the most accurate design will have a large number of small samples if there are big differences between the primary units, and the cost of taking extra samples is low. Conversely, if the compositions of the primary units are similar, and it is costly to include extra primary units in the sample, then the best sampling design will have a small number of large samples (*see* Pope [8]).

A closely related system is *cluster sampling*, which may be regarded as a special case of two-stage sampling when the whole of the primary unit is sampled. Instead of making a random selection of each unit to be sampled individually, they may be taken in groups, the groups being randomly chosen. For instance, in a

plankton survey of fish eggs, two or more hauls may be made at each station. The advantage of more samples being taken with the same expenditure of effort, is partly counteracted by the fact that samples from the same cluster very often, though not always, tend to be similar, so that extra samples from one cluster do not give so much information on the population as a whole. Thus, for a given number of samples the accuracy is likely to be reduced by cluster samples, though it may be increased for a fixed sampling effort, at least for a moderate size of cluster.

A further method is that of *stratified sampling*. The population being sampled may be separated into a number of divisions or strata, e.g., separate areas of the sea for quantitative plankton or benthos surveys, or different size categories of commercial landings of fish. Each division or stratum is then sampled independently, and the estimates from each thus obtained. These are finally combined to give the estimate for the whole population. Such sampling has considerable advantages in decreasing the variance. Also, because truly random samples are more easily taken from within a reasonably small stratum than from the whole population, bias is less likely to occur ; in fact, in some instances, e.g., landings of fish sorted in sizes, random samples from the whole population are virtually impossible, and stratified sampling has to be used. Decreased variance is particularly likely to be obtained when there are considerable differences in the composition of the various strata, e.g., in length sampling from size categories. As in two-stage sampling, there is the likelihood of considerable advantage in using the best allocation of sampling effort between the various strata. The mathematical criterion for the best choice is given by Neyman (3) who shows that the accuracy is greatest when the size of the sample from a given division is proportional to the size of the division, and to the standard deviation within that division of the quantity being estimated. Thus, the biggest samples should be taken from the larger and more variable strata. An example of stratified sampling outside the field of marine fisheries might be the selection of sites for pilot experiments on fish farms. Here, there is a major danger of bias in choosing the sample ponds — supposedly representative of possible future commercial ponds because without a proper sampling scheme the sites chosen may well be more favorable (e.g., nearer markets) than the average. Much of this bias may be overcome by classifying possible sites and taking a sample from each group. Such a classification need only be very rough so long as all possible sites, good and bad, have the proper chance of appearing in the sample.

A further refinement of sampling method sometimes occurs when the measurement of the quantity ultimately required is difficult or expensive. Then there may be another quantity which is closely related to the first, but more easily measured. Then direct sampling may be made for this second quantity and, using a second and usually small sample to relate the two quantities, the

estimate of the quantity of primary interest obtained indirectly. Age composition may often be thus obtained directly through the use of length measurements (which can be done much more quickly than age determinations), as a guide to age. Relatively few age determinations are sufficient to relate age to length. Fuller descriptions of these sampling methods will be found in statistical textbooks e.g., Deming (1), Yates (5), Schumacher and Chapman (4), who also give the fundamental mathematical equations underlying the statements made here concerning the increased efficiency, etc., of the methods. The reader is referred to these for further theoretical studies, and the rest of this paper will be concerned with applying the methods to practical fisheries problems. Particular reference will be made to the problems of population studies, i.e., the use of sampling methods in estimating total catch, effort, species composition, size and age composition, etc., in a commercial fishery.

This paper is intended to give a general introduction and outline of sampling techniques, and their application to fisheries problems. The use of mathematics has been avoided as far as possible, and much of the discussion perhaps lacks some measure of precision. For instance, in discussing the allocation of effort in two-stage sampling, it is shown in general terms that more and smaller samples are required when there is larger variance between the primary units, but the exact value of the best size of sample can only be determined by proper statistical analysis. These methods, and the sampling problem in general, are dealt with by several textbooks (*see* Selected Bibliography).

IV. Sampling for Catch and Effort

Reliable figures for the total catch and fishing effort are essential for an adequate study of any exploited fish population. For some fisheries complete, or nearly complete, information, particularly of catch, is available, and no sampling problem arises. However, in most situations, some sampling system is necessary. A good general outline of such systems, with particular reference to Japan, is given by Yamamoto (9), and a detailed description of a particular sampling system for the Indian sea fisheries with the reasons for chosing it, is described by Sukhatme, Panse and Sastry (7).

Major problems in such a survey are the choice of a sampling unit and the definition of the population to be sampled. Among such choices might be landings by individual boats at individual ports or at one port in one day. These would entail a knowledge of the total number of boats, e.g., through the registration of all fishing boats, or of all ports at which any appreciable quantity of fish was landed. Suppose there were, say, 1,000 boats on the register at the beginning of the year. Then a sample of, say, 100 could be taken, preferably by a proper randomizing method, e.g.,

random numbers, and their catches recorded being equal to, say, 200 tons. Then the estimated total catch would be 200 × 1,000/100 = 2,000 tons. This will, however, only be the estimate of the catches by all boats on the register at the beginning of the year ; to obtain the total catch, the estimated landings by any other boats must be added. There is, of course, no necessity to sample directly for catch ; in India, it was easier and more accurate to sample for catch per trip and for the total number of trips, multiplying the two together to obtain the estimate of the total catch.

When sampling for total catch, a design using a properly chosen system of stratification is usually advantageous. If the fishing boat is the sampling unit chosen, the stratification by size of boat will give greater accuracy, both by reducing the variation in catches between different boats, and by enabling a bigger sample to be drawn from the bigger boats, e.g., sampling half the boats in the largest group but perhaps only one in twenty from the smallest. Again, if there is marked seasonal variation, stratification by time would give the same two advantages, with frequent sampling during the time of heavy landings, and less often during the off-season. Statistics of total catch may be required in terms of weight, value, numbers or volume, and the remarks above are applicable to any measure required. Often more than one measure is required, such as weight and value, or else, say, the catch in numbers is needed when only the catch in weight is known or readily estimated. Then the information might be obtained by taking rather few special samples in order to relate the various quantities, e.g., the number of fish per unit weight of the catch. The usual precautions against bias must be taken, e.g., that the samples taken do not contain too many small fish. Suitable stratification will be useful, for instance, dividing the fishing season or area into parts which are likely to differ in average size or value of the fish.

Statistics of catches and landings are often treated as being synonymous but, particularly in northern Europe and America, there is considerable rejection by fishermen at sea of both unwanted species and unwanted (usually small) specimens of commercially valuable species. Accurate statistics are generally only available for landings but in many calculations, particularly of the effect of fishing on the stock, data on catches are required. Only someone at sea on the fishing boat will be aware of how much fish is rejected, but fishermen will generally be too busy to keep regular records of the quantity rejected. Thus, complete statistics of quantities rejected are very unlikely to be obtained, and, if obtained, are likely to be inaccurate. A sampling survey, either by sending special observers on fishing boats, or by obtaining special co-operation of a sample of the fishermen, may be necessary. The latter method is, or may be, an example of the not infrequent occurrence of a sample survey being more accurate than a complete survey. Busy fishermen may well be prepared to keep accurate records

of fish rejected on, say, one trip in twenty where they would not do so every trip. Special observers at sea, though securing accurate data for those trips on which they are present, involve a great expenditure of manpower, especially when the fleet is composed of many small vessels. However, in a fleet of a few large vessels, as the Grand Bank salting fleet, the observations on one ship make up an appreciable part of the total. If the special observer can also carry out additional examinations of the catch, such as for size, maturity, feeding, etc., then the quantity rejected may be estimated both accurately and cheaply.

The fraction rejected usually varies very markedly both with season and fishing ground, and increased accuracy and probable reduction in bias, will be gained by a suitable use of stratified sampling. Within one strata, i.e., on the same ground during one season, the fraction rejected is likely to be fairly constant, though possibly varying noticeably from one year to the next, e.g., being large when a strong-year class is just below commercial size. Thus, the accuracy obtained is likely to be high, even within very few samples ; even half a dozen samples within each strata should give estimates of quite serviceable accuracy. Certain seasons or grounds, particularly spawning grounds, may be known to give negligible or even no rejection of small fish, and thus may be omitted from the sampling system, permitting an increased intensity of sampling at other grounds.

The natural sampling unit is the single trip by a fishing vessel, and directly the sampling would be for the fraction of the total catch rejected. Thus, observations and records might be obtained from twenty trips by various ships from one ground showing that during these trips 30 tons of fish were rejected, which were equivalent to 5% of the 600 tons of fish landed from the sampled trips. Raising this sample to the total catch from the particular ground, say 6,000, gives the estimate of the total quantity rejected as 5% of 6,000 = 300 tons. The total quantity rejected from other grounds (i.e., different strata of the sampling system) is obtained similarly, and added to give the over-all total.

If the information is to be obtained from fishermen's records rather than by special observers, two procedures are possible : either to obtain a sample of fishermen who would give complete records from all their trips, or to get records from all fishermen, but each one only providing records from a small fraction of all his trips.

The first system would have the serious drawback of being in no way a random sample, including only the more co-operative fishermen. In particular, not improbably, few fishermen using small mesh or blinded nets and catching small fish, would be included, and the estimates of the proportion rejected would be biased, being too low. Before accepting as unbiased the estimate obtained from the data received, it is important that some check be made as to how much the fishermen who have not reported back are

likely to deviate from the average, e.g., by consideration of the size composition of the fish actually landed.

Further sub-sampling of the complete trip will probably give increased economy of effort with little loss of accuracy within one trip. The proportion rejected on one ground is fairly constant, so that records of the quantities retained and rejected from only a small number of hauls will determine well the proportion rejected and, hence, knowing the quantity landed from the complete trip, the total quantity rejected.

Effort statistics are generally used for one of two purposes, economic or biological, and though usually the same unit, e.g., number of days at sea, number of fishermen, has had to serve both purposes, the two are distinct. The distinction is best brought out by considering how the introduction of more efficient gear, e.g., the Vigneron-Dahl gear in the North Sea trawl fishery in the 1920's, may be shown in the statistics of a fishery. To the economist the effort should appear constant, but the catch per unit effort to rise. To the biologist the effort should increase, and (on constant stock density) the catch per unit effort remain constant. The choice of the best unit fishing effort for biological use has been discussed fully by Beverton and Parrish (8) ; they show that proper statistics of fishing effort require very detailed information on the fishing activities of each vessel. Such information, as opposed to the usually somewhat simpler "economic" effort statistics, is very often unobtainable for the whole of the fishery, and some sampling scheme may be necessary. In such a scheme, accuracy will be increased and the chance of bias reduced by sampling for catch per unit effort, and using a knowledge of the total catch, rather than by sampling for effort directly. If the difficulty in the collection of effort data is confined to a fishery exploiting the same stock as another for which adequate data is available, then the effort of the first fishery may be estimated at once from its catch, and the catch per unit effort of the second fishery (c.f. Beverton and Parrish) ; i.e., the effort in the first fishery is given by the product of the catch and the ratio of effort to catch in the second fishery.

Sampling of Catches : Direct

The study of catches of fish, whether by research vessels, or by ordinary commercial ships, for species, size, age, maturity or other characteristics, is one of the most common tasks in fishery biology, and one that often involves some sampling system. Of the many observations that can be made, one of the most frequently used is length, which can be quickly and accurately performed. Length is usually closely related to many of the other factors of interest — weight, age, maturity, etc., so that the latter may often be most easily determined from the length data plus a small key sample relating length with the factor concerned, which may

be examined in the comfort of the laboratory. The following section will, therefore, mainly be concerned with *sampling for length*. However, the principles and methods developed are equally applicable for any other characteristics — age, maturity, etc. — for which samples may be taken directly from the catch. For instance, it will be shown that when a very small sample (half a dozen fish) is taken from the top of a pile of fish, this will be biased towards taking fish longer than the average. Equally, it will be biased towards taking fish older than the average, and the remedy is the same — taking all the fish within reach as the sample, so that possible personal selection cannot introduce bias, either in length or age.

On research vessels, the sampling problem may not be very important. Often the total catch is comparatively small — perhaps only a couple of hundred fish, which can be handled quite easily. Important in choosing whether to sample the catch, and the size of sample to take, is the fact that the catch of a research vessel is not *per se* of great interest. Usually the research vessel is itself a sampling instrument, and its catch is only important as being, for example, a sample of the fish present on the grounds. This primary sampling by the ship may be highly variable, and quite a small secondary sample of the ship's catch may be big enough to have an accuracy well within the variability of the primary sampling. A good example of this in a slightly different field is in plankton work. The haul-to-haul variation, even at the same station, is very large and thus sub-sampling (in this case, in the laboratory) of the catch — even as small a fraction as a few percent — causes sampling errors well within the variance of the original data. A considerably greater degree of sub-sampling than that generally used would in all probability not involve any loss of accuracy. On board research vessels there is not always alternative work available which may be done in the time saved in taking smaller samples. Thus, measuring a very large proportion of the catches of the research ship when a smaller sample would be adequate may not be particularly useful, but it is not necessarily wasteful.

Taking small samples is only correct, even when the variance is small, as long as no bias is introduced, and, in fact, elimination of bias is probably the main problem in research vessel sampling. The first batch of the catch picked up from the deck usually contains the bigger fish, the very smallest fish being left on deck and picked up last. Thus, a haphazard sample picked out from the catch may be very highly biased, with an average size much greater than the true mean. Such a bias has been found in some samples of cod taken on board the British research ship *Ernest Holt*. At several stations two samples were taken, one of a hundred or more fish, which were measured, and the other of twenty or so fish, taken haphazardly for age determination, sex, maturity, etc. The fish in this second sample were nearly always bigger, sometimes as much as 10 cm. longer.

If the total bulk of the catch is not too great, then it may all be picked up and redistributed, a few fish at a time into, say, four groups. One group then gives a sample of one quarter of the total catch. Alternatively, if the catch is large, when it is still lying on deck, a section (e.g., half one of the fish pounds), may be taken as the sample (making sure that the smaller fish are not left behind). There is some possibility of bias in this second procedure if, say, the sample is taken from the aft end of the catch, where there is also a tendency for the larger fish to fall. However, unpublished analysis by Beverton on measurements of a different section of the catch, made on board the *Ernest Holt*, showed no significant differences.

Sampling of Landings

The knowledge of the size and age composition of the commercial catches is very important, whether regarded as giving information on the composition of the stock, or merely on the toll taken from the stock. Sampling of commercial catches, therefore, makes up a large and increasing amount of fishery research effort. Some of this sampling may be done by special observers on board commercial fishing vessels. Here, the sampling problems are the same as on research vessels, though the practical problems of obtaining a proper sample without interfering unduly with the normal fishing routine may be considerable. More often sampling is carried out on shore after the ship has returned to port. The first essential is to ensure unbiased sampling. A sample of fish taken after the catch is sold, is very likely to be biased and unrepresentative, as it may be divided among many different merchants, each of whom has bought a size or quality of fish most suited to his purpose (filleting, curing, etc.). Sampling, therefore, should be done, if possible, directly the fish are landed. In England, this is facilitated by the custom of selling the fish by auction. The demersal fish are landed early in the morning and laid out on the fish market, sorted into species and, for the more important species, into different sizes. Between the time the fish are landed — any time from midnight onwards — and the time they are sold (7 to 8 a.m.), there is usually ample opportunity to measure any required sample. Herring landings at English ports are rather different in that ships return from the grounds during the day, though mostly in the morning, land their catches, and often sail again immediately. There is usually time, however, before the fish are divided among the buyers, to measure a small sample, and thus eliminate a possible source of bias.

The obvious choice of a primary sampling unit is the catch of one ship. For the English trawler landings there seems to be no particular problem in choosing the ship, e.g., of introducing bias. However, for drifter landings, there is likely to be some correlation between the distance of the fishing ground from port

and the time of landing. Thus, the convenient system of taking samples at the same time each day is likely to over-represent one ground and hence may give a biased result. This may be overcome either by ensuring a more even distribution of sampling through the day, or by some system of stratification, e.g., by dividing the landings according to the area fished, and taking a certain number of samples from each area.

When the catch is laid out for sale, a sample may be taken quite easily. In England, the fish are put into barrels or boxes and a natural sample is one or more complete boxes. Such a sample is free from the possible bias of selecting the larger fish from a pile. Sometimes, when they are very small with several hundred in a box, a sample may be only part of the box, and then risk of bias must be eliminated by taking the sample as all the fish from one preselected corner of the box. When the catch is large, it is physically more convenient to take the sample box from the edge of the array of boxes. This is a non-random sample and, therefore, before using it a check should be made as to whether there is a difference in any of the quantities being sampled (species, length, age, maturity) between fish in the boxes near the edge and those near the center.

An essential part of working-up the data from such a sampling scheme to give an estimate of the composition of the catch is the knowledge of the quantities to which each individual sample refers. For instance, in a sampling scheme designed to give the total landings of two species not distinguished by the fishermen, three samples from different ships were taken, and gave percentages of one species of 40%, 60% and 50%, respectively. These may only be readily combined if the quantities landed by each ship are known ; if they were, say 1,000 kg., 2,500 kg. and 1,500 kg., respectively, then the total of the first species would be 400 + 1,500 + 750 = 2,650 kg., out of a total of 5,000 kg., i.e., 53%. (Note that this is not the mean of 40, 60 and 50%).

Within such a sampling system, there remains a choice of method, as between taking very large samples from each ship but sampling only a few ships, and taking a large number of samples, each of comparatively few fish. Research on British markets has shown that the catches of ships differ considerably, and extensive sampling from one ship can give but limited information on the catches of others. Therefore, despite the time spent moving from one ship to another, which reduces the number of fish that can be measured in a given time, the variance of the estimates obtained is least for samples of very few fish. The most convenient size of sample, taking into account the risk of personal bias with very small samples, has been found, for English trawl catches, to be about 50 fish. This may serve as a rough guide to the best size of sample in other conditions. Another is that, in England, about equal time is spent actually measuring fish and moving gear, etc., from one sample to the next.

Often the total catch of one species may be separated into several categories, based on the size or condition of the fish. In effect, this produces a stratified sampling design, and if the sorting into sizes is at all consistent, the accuracy of the estimated size composition, for a given amount of sampling, will be greatly increased. A sample must, of course, be taken of every category; this is obvious when there are only two or three major categories but, for instance, at Lowestoft, a certain number of thin and poor quality plaice are sorted separately. These are only a very small proportion of the total catch and are economically unimportant but may contain a considerable proportion of the very large fish, and a serious bias towards underestimating the average size would be made if these thin fish were not included. The calculations needed to estimate first the composition of the catch of the ship sampled, and then that of the total landings, from samples taken from each category of one ship, are illustrated in the following table, taken from Gulland (8). The figures are typical of a landing of plaice by a Lowestoft trawler.

HYPOTHETICAL EXAMPLE OF CATCH BY CATEGORIES OF A LOWESTOFT TRAWLER

Catch		Large	Medium	Small	Thin		Total
Weight landed (stones*) = A		30	100	480		620	10
Weight measured (stones) = B		10	5	3	10		
Raising factor = A/B		3	20	160	1		
Length group (cm.)	25-29	30-34	35-39	40-44	45-49	50+	
Number measured (Large C)	—	—	—	16	33	15	64
Number measured (Medium D)	—	2	47	27	—	—	76
Number measured (Small E)	26	41	8	—	—	—	75
Number measured (Thin F)	—	—	7	15	14	14	50
Estimated number landed (Large C × 3)	—	—	—	48	99	45	192
Estimated number landed (Medium D × 20)	—	40	940	540	—	—	1 520
Estimated number landed (Small E × 160)	4 160	6 560	1 280	—	—	—	12 000
Estimated number landed (Thin F × 1)	—	—	7	15	14	14	50
Estimated number landed (Total)	4 160	6 600	2 227	603	113	59	13 762

* 1stone = 14 lb. = 6.35 kg.

The table shows how the measurements in each category are multiplied by the correct raising factor (the fraction of that category actually measured) to give the estimated numbers of each 5-cm. length group.

The numbers in each category are then totaled to give the numbers in the whole catch of the ship. It should be noted that the raising factors for the categories vary considerably, and that without knowing the catches of each category, it would be impossible to convert the measurements taken into a length-composition of the whole catch.

If the total landings by all ships are divided into categories in the same manner, then these categories can be used as before as a stratification. That is, the landings of large, medium and small fish by the sampled ship are treated separately as samples of the total landings of each category. Alternatively, with, of course, some loss, the sampled catch can be treated as a single sample from the total landings.

Many other stratifications of the commercial landings are possible, e.g., date of capture, place of landing, method of capture, etc. Such stratifications are most important in reducing bias ; often, either for convenience or by habit, sampling will be concentrated at one place of landing (e.g., that nearest the laboratory), or on fish caught by one type of gear. If there is any systematic difference between ports or gears then bias, often to a serious extent, is introduced. For instance, as described by Rollefsen (8) in the Lofoten cod fishery the samples were originally taken mainly from the traditional long-line fishery. The recently introduced purse seine caught noticeably more large fish and the long-line samples alone would seriously underestimate the number of large and old fish landed. Thus, to get an unbiased estimate for the total catch, samples had to be taken from all types of gear — the question as to what samples, if any, provide unbiased estimates of the true stock is distinct and much harder to answer. Some methods of dealing with it will be discussed later in this paper.

Also in the Lofoten fishery, there are considerable changes in the size, age and sex composition during the season, and from one ground to another. The landings have, therefore, to be subdivided according to time and place of landings, and samples taken from each sub-division. The best degree of sub-division will depend on the degree of differences between possible divisions, also on the number of samples available. The necessity of having at least one sample from each sub-division will often provide a definite limit. The divisions need not be taken at regular intervals ; for instance, if samples are being taken for maturity stages throughout the year, it is likely that this will be changing most rapidly at and near the time of spawning. Thus, the spawning season may be divided into weekly intervals, and the rest of the year into months.

V. Indirect Sampling

Many of the quantities of major interest in research (age, racial characteristics, etc.) are difficult or slow to determine, and cannot be easily and quickly measured in samples on the fish market. Again, several of these quantities are closely related to the length of the fish. Thus, direct sampling as described in the previous section, may be advantageously replaced by the use of a large number of length samples, and a relatively few key samples, used to relate length to the characteristic required. This process

may be illustrated by the samples and calculations used to estimate the number of six-year-old plaice landed by English trawlers. The number of fish in each 5 cm. length group landed is estimated directly from measurements carried out on the market. Suppose the totals in the 25 to 29 cm., 30 to 34 cm., and 35 to 39 cm. groups are 40,000, 60,000 and 20,000, respectively. At the same time, a small sample of 200 fish may be taken from each length group, and their otoliths used to determine their ages. Of these otolith samples, 10 (5%) of the 25 to 29 cm. group were six years old, 80 (40%) in the 30 to 34 group, and 20 (10%) in the 35 to 39 group. No six-year-old fish above 39 cm. long was found in the otolith samples. These percentages are estimates of the percentage of six-year-old fish in the total landings of fish of that size ; hence the estimated number of six-year-old fish landed between 25 to 29 cm. is 5% of 40,000, i.e., 2,000. Combining the three length groups gives the total number landed as 2,000+ 24,000 + 2,000 = 28,000. The array giving the precentages of each age within each length group has often been termed an age-length key. First used by Fridriksson (6), it has since been used in many fisheries. Other keys, e.g., maturity-length, can be set up equally well. The process of converting length to age is a purely mathematical one and makes no assumptions about the relation of age to length, i.e., the growth pattern. The only assumption is that the small otolith (or scale, etc.) sample, is a random one of all fish of that size, at least as regards age (or maturity, etc.). The growth pattern does have a bearing on the improvement in precision, i.e., the reduction of variance achieved by the method. If the growth is rapid and uniform then age is very closely related to length, and a very small sample will enable the age to be estimated accurately from the length. Conversely, if the growth is slow and irregular, a large sample is necessary to reduce the variance to the same level.

The length-age relation within a stock of fish is often less variable than length or age distribution alone. In particular, age-length keys obtained for the same stock from catches of different gears or of different countries are likely to be the same. For instance, the length distributions of plaice caught by English vessels in the central North Sea show that seiners catch more large fish than trawlers. Thus, samples from trawl catches alone would give biased estimates of length or age composition of the total catch. However, it seems perfectly valid to make only length measurements from seiners, and use an age-length composition of seiner catches. Two possible sources of bias are a difference in the areas of fishing, such that one gear is fishing on areas of higher average growth rate, or that one gear may be selective for fish of a high (or low) growth rate. This appears very unlikely for trawls, but could be possible for a hook and line fishery where the faster growing and hungrier fish might be more easily caught. Besides invalidating an age-length key from either gear, such a selection is

of basic importance in that any estimate of growth rate obtained from the selective gear will have a bias.

The chances of either source of bias occurring may usually be fairly easily determined. If they are negligible, the use of an age-length key determined from one part of the fishery only, plus length measurements from the rest, will prove useful, especially when for practical reasons the detailed sampling has to be confined to part of the fishery, e.g., in an international fishery, when some countries may have only limited research effort available for sampling. The extension of the method to cover data from the fishery in years other than that in which the age samples were collected is dangerous, because both the growth rate may have changed and, more commonly, the relative strengths of year classes will change. However, it may be helpful, when used with care, in interpreting past data of length compositions alone, and in making rough assessments of mortality rates etc., from them.

VI. Sampling the Stock in the Sea

Many of the statistical problems occurring in sampling the actual fish stocks are common to other fishery and oceanographic problems, e.g., plankton surveys. In planning survey work with a research vessel, whether using plankton nets, bottom samplers, or trawls, the main sampling problems are the same — the choice of gear and the size and frequency of samples — i.e., whether to take half-hour or three-hour hauls, and how far apart to have the stations. All or nearly all marine sampling implements are strongly biased, and sample representatively only a small proportion of the true population. For instance, a fine meshed plankton net will allow the larger and more active plankton animals progressively to escape, while a coarser meshed net will seriously underestimate the small diatoms. Moreover, the amount of this second bias is likely to be highly variable, depending on the degree of clogging of the meshed by the catch of plankton. Such effects occur with most sampling instruments, a well-known but not exceptional instance being the escape of small fish through the meshes of a trawl. The best choice of sampling instrument for the problem concerned is, therefore, the essential first step of any sampling problem.

The distribution of organisms (fish, plankton, etc.) in the sea is usually extremely patchy, giving wide differences between samples. These differences are both marked and consistent ones between large areas, and random within an area. Catches of plaice in the southern part of the North Sea are, on the average, much higher than in the north, definite good fishing grounds being unknown within these areas. However, single hauls on the same ground, and apparently under the same conditions will give catches differing by a factor 2 or more. The general conclusions from these facts are, first, to use stratified sampling, i.e., to divide the whole area into sub-areas with more nearly uniform conditions, and sec-

ondly, to take as many samples as possible, even at the cost of reducing the size.

The most obvious choice of method of stratification is by broad geographical regions ; within these regions more detailed division is possible. For bottom living animals (including demersal fish) depth is a very important factor, and stratification by depth-zone will give improved accuracy. Within any stratum the position of sampling should be chosen randomly. In practice, the difficulty in using stations all chosen randomly and independently would be very great, and a systematic grid (i.e., lines of stations at regular intervals) is preferable, with merely the precise location of the origin of the grid being chosen at random. Further, because the lines of latitude and longitude are effectively artificial concepts, they may be considered as random relatively to the natural population, and thus form a convenient grid along which lines of sampling stations may be taken. The exception would be when there were definite trends running north and south (or east and west). Here, and anywhere where there is a marked trend, further stratification seems useful. Suppose there is a coast line running north and south and, say, the number of fish caught by hook and line decreased with the distance from the coast, then the whole area would be divided into strips parallel to the coast, and the appropriate sampling pattern would be lines east and west perpendicular to the coast, with each line having one or two stations in each strip.

The sampling pattern particularly to be avoided is one in which the positions of stations, within the finest stratification used, are chosen with reference to the characteristics being sampled. For instance, it is tempting when fishing to determine the relative abundance and other characteristics of a fish stock, to do so at points where it is known that good catches, and hence big samples for, e.g., racial investigation, are probable. So long as the habits of the fish are unaltered, the data will give reliable estimates of the relative abundance of fish. However, if the fish change their grounds, the catches will go down, apparently as a result of a decrease in the stock. This effect of bias introduced by taking most samples where the fish are most abundant is quite distinct from stratified sampling, where these divisions containing the greater abundance may also contain most samples, but within any division the samples are random, and independent of fish abundance.

The intensity of sampling — how far apart to have the station — is mainly determined by three factors : the variance between estimates from different stations ; the time taken to move between stations ; and the time spent sampling on any one station. The problem is, therefore, analogous to the two-stage sampling discussed previously, and as before the exact solution can only be determined from data of the particular problem concerned. Increased variance between samples requires more samples, increased time on one sample implies fewer samples. The similarity with previous two-stage

sampling problems is even closer when there is the possibility of increasing the size of sample at any station, e.g., by taking more than one haul with a plankton net, or using a two- or three-hour haul with a trawl, rather than a half-hour one. Other important factors are the variance between different samples at the same station, and the time spent at a station, but not actually sampling (e.g., the time spent shooting and hauling a trawl). The combination of the various factors suggests that, with a sampling instrument giving discrete samples (vertically hauled plankton net, bottom grab, etc.), a single sample at each station is most efficient (gives the least variance). For ordinary trawling, a duration of half to one hour is likely to be best. For other gears, e.g., Agassi trawls, towed plankton nets, a single short tow at each station is probably most efficient, subject to its being long enough to give a sample of reasonable size.

Data of catches by commercial vessels can be regarded as providing samples of the natural fish stock, as well as being of direct interest in themselves. Because normal commercial operations are on a much larger scale than most possible research vessel surveys, the estimates obtained will have small variances ; unfortunately, they will also often have a high degree of bias, both as abundance indices, and as samples of the composition of the stock (by species, age, size, etc.). Some of the bias will be caused by the gear used, and a knowledge of its selective properties may enable correction factors to be used, or at least limits to be set to the reliability of the data (e.g., in a trawl fishing, knowledge of the mesh selection and the mesh in use determines a limit of size above which data is reliable, at least as regards selection of the gear).

Bias will also be introduced because ships will fish in preferred grounds, i.e., in a distinctly non-random manner. For the large scale geographical distribution this bias can be eliminated and the variance of the estimates reduced by the usual method of stratification, i.e., provided the information obtained is adequate, the fishing region may be divided into sub-areas, within which conditions are more nearly constant. Such divisions may be used to calculate effective over-all fishing effort, an index of density (as given by catch per unit effort), species composition, or size composition, etc. The calculation for fishing effort is most widely known, but the other applications are equally useful. The estimate for the whole population is obtained as before as the sum of the individual estimates from each stratum, and, therefore, necessitates knowing the size of the population within each stratum, at least in relative terms. The absolute magnitude of a fish stock within any area is generally at best known only within wide limits; however, the relative magnitude of the density of the fish stocks within different areas will usually be given well enough by the catch per unit effort. The relative abundances will then be the catch per unit effort times the area of the region. Suppose that the rel-

ative abundance of cod and haddock within a region has to be estimated ; in any one position, the catches of a trawler give a fair estimate of the abundances, but the ships tend to fish in that part of the region where there are more haddock. Then the region may be divided into, say, two smaller regions. The first of these has an area of 200 sq.mi. (518 km^2), and from it the catch one year was 700 tons of haddock, 300 tons of cod, and the fishing effort, in some units, 100. The other sub-region has an area of 500 sq.mi. (1,295 km^2) and gave catches of 100 tons of haddock and 300 tons of cod, with a fishing effort of 50. The catch per unit effort in the two regions is 10 and 8, respectively, which with the difference of 2:5 in the areas give weighting factors of 20:40, i.e., 1:2. Therefore, the percentage of cod may be given as $^1/_3$ (30 $\times$ 1 + [75 $\times$ 2]), i.e., 60%. In contrast, the proportion in the catch is 60 tons out of 1,400 tons, i.e., only 4.3%. These data can be used to show other types of calculation ; e.g., using the catch per unit effort as the index of density, the densities of haddock in the two regions are 7 and 2. The average density over the whole region is, therefore, given by combining these in the ratio of the areas of the two regions, and is $^1/_{700} \times (7 \times 200 + [2 \times 500]) = 3.43$. Similarly, the over-all density of cod is $^1/_{700} \times (3 \times 200 + [6 \times 500]) = 5.14$. (This gives a combined density of cod and haddock of 8.57, 60% of which is 5.14, agreeing with the previous estimate of 60% cod).

The size of sub-division used may be different for the analysis of different factors. For density, i.e., catch per unit effort, which is variable, and for which a large number of samples (reports of catch and effort by individual boats) are available, very detailed sub-divisions are possible. For instance, the Japanese data on long-line fishing in the Pacific is divided into 1 degree squares, which gives information from several hundred different sub-divisions. Because of the vast size of the whole region the sub-divisions are several thousand square miles in area, but in other fisheries sub-areas down to a few square miles would be possible.

For analyzing more specialized data, e.g., age compositions, which are likely to be less variable and for which fewer samples will be available, larger sub-divisions will be necessary, e.g., the Japanese long-line data are analyzed by areas five degrees square or more.

Because the amount of stratification can be increased only so long as there is at least one sample from each stratum, there is a very definite lower limit to the size of sub-area used. In practice it may be convenient to collect data from smaller sub-divisions, which for analysis can be combined (especially from the fringes of the fishery). However, even within the smallest division possible the distribution of fishing will be distinctly non-random. The degree of non-randomness (the degree to which the fishermen can find and concentrate on the fish), will tend to remain constant, i.e., the ratio of catch per unit effort of the commercial gear to the true density of the fish stock will remain constant. In par-

ticular, if the fish change their preferred ground, the fishermen will follow them and the catch per unit effort will remain unchanged (compare this with the results of fixed surveys by research vessels). As the fishery develops, and new techniques such as echo sounding are introduced, the fishermen may be able to concentrate better, so that the catch per unit effort is only a good index to density within limits. The problem of the exact relation between the two is beyond the simple study of statistics and sampling.

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NET MATERIALS OF SYNTHETIC FIBERS [1]

Introduction

Since net fishery first began some thousands of years ago, natural fibers, mainly of vegetable origin, have been used for making the nets. Bast fibers from different plants held first place as the raw material for nets and lines. It was, therefore, an important event in the history of netmaking when cotton began to replace linen and hemp in the second half of the last century. This was the beginning of a revolution, leading to the construction of the first nets of man-made fibers in the last years of peace before World War II.

Man-made, or truly synthetic, fibers are produced without the help of fiber-forming raw materials of vegetable or animal origin, such as cellulose or protein base fibers. The truly synthetic fibers are manufactured from polymers, which are synthesized by laboratory processes from simple chemical units. These fibers belong to the plastic materials now so important. The history of plastics will not be discussed here, but one important fact should be remembered. The qualities of truly synthetic materials can be influenced to a certain extent by Man and, further, during manufacture and processing to twines, etc., modifications can be introduced to meet the wishes of net-makers and fishermen.

These processes are still under experimentation and new discoveries are made every day. This paper will give a resumé of the qualities of the man-made fibers known at the present time.

I. Qualities of Net Materials

Man-made fibers in four different forms can be used for the construction of gear :

A. Twines made of staple fibers (spun fibers).
B. Twines made of continuous fibers or filaments.
C. Monofilaments, i.e., a single filament of a suitable diameter.
D. Multifilaments, i.e., twisted monofilaments.

Some of the new fibers are manufactured in all four forms with common qualities based on the material itself, but each form having specific qualities according to its construction.

The following section discusses qualities which are specific to the material :

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[1] By Dr. A. von Brandt, Professor and Director of the Institut für Netz- und Materialforschung, Hamburg, Western Germany.

1. *Resistance to Rotting*

Synthetic fibers are never attacked by microorganisms. This is without doubt the principal advantage of truly synthetic fibers and the reason why they are rapidly taking the place of the classical natural fibers in fishing gear manufacture. There is no danger of rotting by immersion of long duration or by storage. It is very important for a fisherman to know that he does not have to spend time, money or labor on rotproofing such gear. In natural fibers, antiseptic treatment can only postpone, but not prevent, final destruction.

Yet it cannot be said that all types of man-made fibers are also equally resistant to attacks by rodents, insects or crabs. Twines of synthetic fibers, however, lose some of their breaking strength in the water by long immersion (see *Figure 1*). In this case, the reason of the decrease of strength is not rotting.

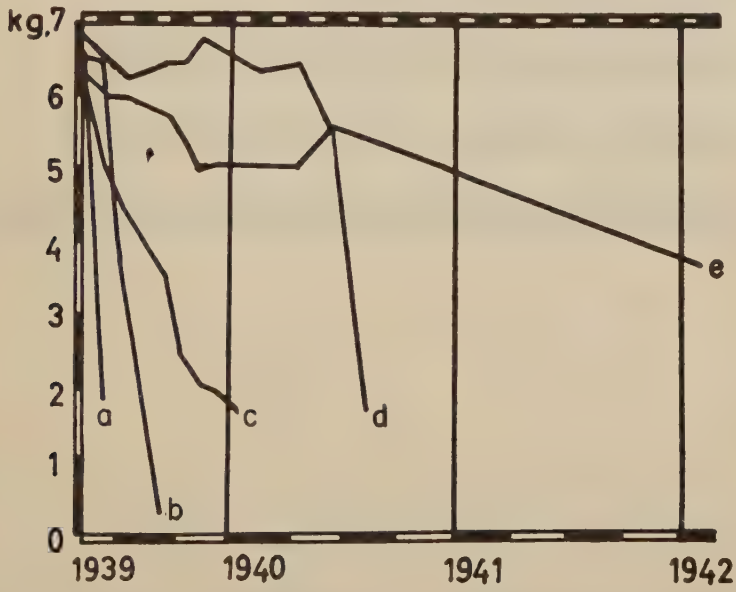
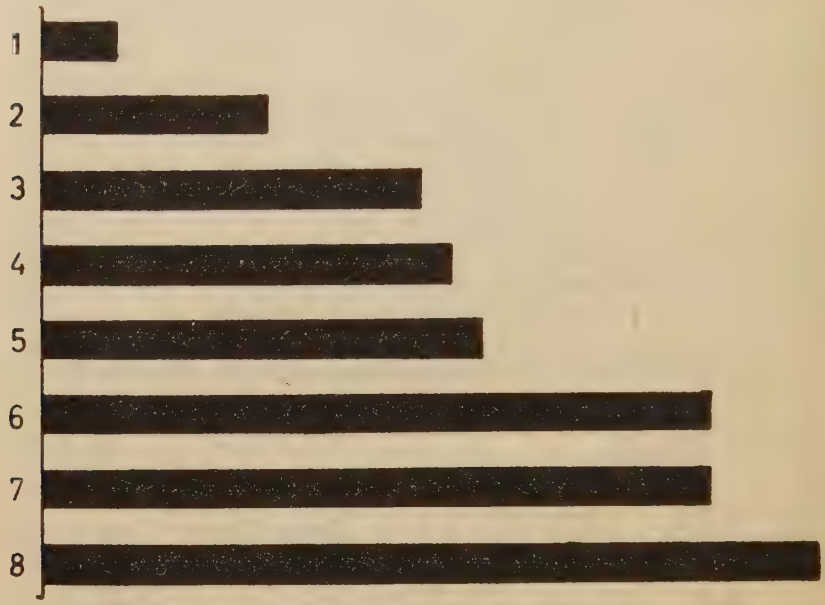


Figure 1. Decrease in strength of different net twines after long immersion.
a. Cotton — unpreserved ; *b,c,d.* Cotton — preserved ; e. PeCe twine.

2. *Resistance to Sunlight*

In the open air, textiles can be destroyed by weather, including the destructive influence of sunlight, moisture, aerial microorganisms, dust and temperature. The most import factors are the ultraviolet rays of the sun. All natural fibers will be weakened by long exposure to weather influences. Some of the man-made fibers also have only a small resistance to daylight. It is, therefore, important for the fisherman to know that some of these

materials — not all — need care to prevent deterioration of their breaking strength and should not be exposed to sunlight (see *Figure 2*).



(Courtesy Klust 1957)

Figure 2. Resistance to sunlight of different net materials.

1. Perlon delustred
2. Perlon bright
3. PeCe
4. PVA fiber
5. PVA continuous
6. Polyacrylonitrile
7. Orlon
8. Rhovyl

3. Resistance to Heat

Net material of cotton, for example, remains undamaged by boiling. Boiling water has to be used if the fisherman wants to preserve or dye his gear. Some of the man-made fibers are thermoplastics which tend to soften at a low degree of heat. The meshes of nets made of this type of fiber with a low softening and melting point can shrink, the material become hard, show a loss in strength and be completely destroyed.

4. Resistance to Chemicals

Some man-made fibers can be damaged by chemicals, cold or hot. For instance, methanol, ethanol or phenol, contained in tar, can dissolve some of these fibers. Even cutch can weaken them.

It is not always favorable to use white net materials for fishing gear. Colored nets sometimes bring higher catches. In such cases tests should be made as to the possibility of dyeing the synthetic net materials as customary in the local commercial fishery, and as to how losses can be prevented.

5. *Specific Gravity of Fiber*

Most vegetable fibers have a specific gravity near 1.5. The specific gravity of the man-made fibers varies in most cases between 1.1 to 1.4. They are lighter than cotton. Some new fibers which have a specific gravity as low as 1 can be made into corkless floating nets. The density of other types is about 10% higher than that of cotton. This results in a higher sinking speed and a better shape of the fish net under water as it will not be easily swayed by the tidal current. There are so many kinds of fishing gear and fishing methods that it is necessary to choose carefully the right type of fiber for each.

6. *Resistance to Water*

All synthetic fibers have a high natural resistance to internal wetting (absorption). The nets dry immediately they are pulled out of the water. Sometimes the absorption is so low that qualities such as strength or flexibility are not influenced at all. In other cases, strength, flexibility, diameter or length of the net material of truly synthetic fibers is changed, sometimes decreasing or increasing in the contrary direction of twines of cotton and other natural fibers. This deformation should be known in each case to meet mesh regulations (see *Figure 3*). Shrinkage and increase in length are influenced by the method of manufacture of the twisted twines, braided lines, etc.

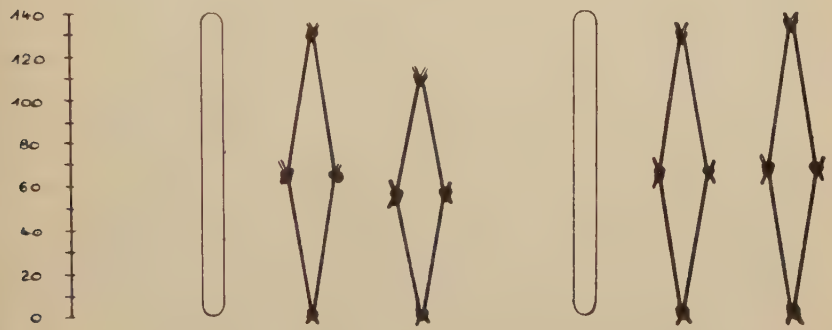


Figure 3. The effect of immersion on mesh size.

Left to right : Manila twine double, circumference of spool 140 mm. mesh dry and wet (mesh becomes smaller). Perlon plaited double, circumference of spool 140 mm.; mesh dry and wet (mesh becomes larger).

7. *Resistance to Fouling and Attack by Animals*

Another quality, specific of the material, is its resistance to fouling, (i.e., the growth of seaweeds, small animals, etc., on gear or ropes immersed in the water for a long period). Some boring animals can destroy textile ropes as well as the wood work of gear.

Some crustaceans and insects (e.g., Caddis larvae) can destroy nets to such an extent that fishing is interrupted. Some man-made fibers seem to be more attacked than natural fibers. It is difficult to find protective treatment. Monofilament, man-made fibers, however, are rarely destroyed in this way.

Other specific qualities are more or less influenced by the production.

8. Breaking-strength

The breaking-strength is very important to all gear. It is the quality tested first by fishermen. A strong fiber allows finer twines which will generally bring bigger catches. The criterion is the knot strength of the wet twines and not the dry strength or

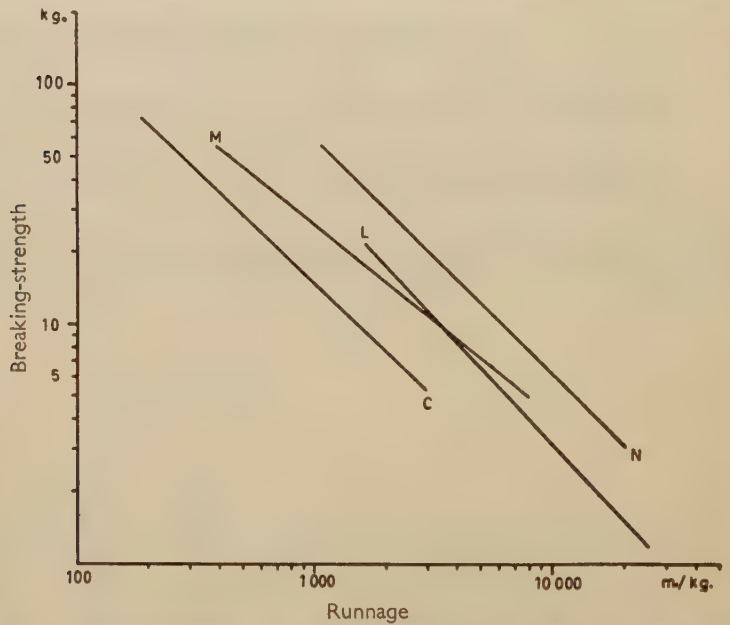


Figure 4. Breaking-strength, dry, of net twines. Nylon gives the best results, followed by Manryo, flax and cotton.
C – cotton ; L – flax ; M – Manryo ; N – nylon.

the wet strength of a straight twine. Cotton twines, for instance, lose about 25% strength if wet knotted, and some high tenacity yarn will lose more than 50%. *Figures 4, 5* and *6* give a comparison of the strength of 4 different natural and synthetic net twines dry, wet and wet with single knots, showing that some net twines in dry condition are very much stronger than others. Their superiority diminishes if they are wet and knotted. The decrease in breaking-strength at the knot is greater with twines of man-made fibers than with natural ones. Most fishermen are not aware of

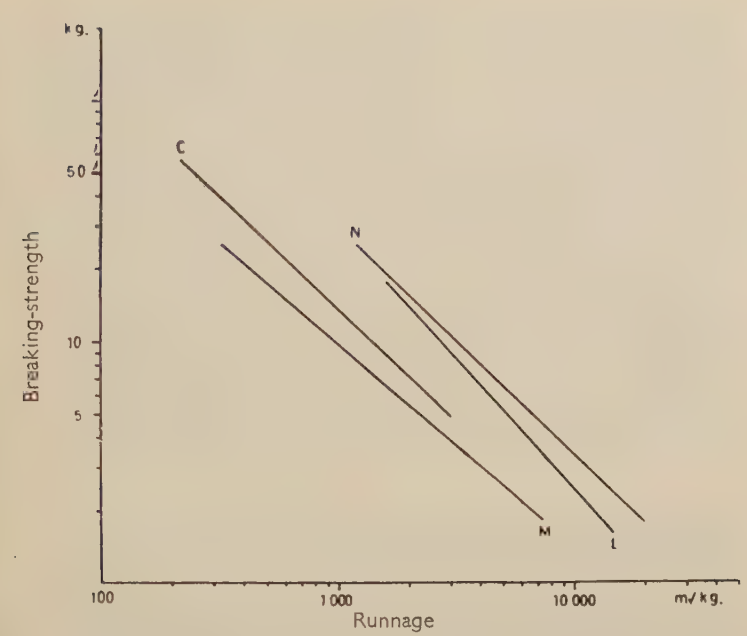


Figure 5. Breaking-strength, wet, of net twines. Nylon and flax give the best results, followed by Manryo and cotton.
C – cotton ; L – flax ; M – Manryo ; n – nylon.

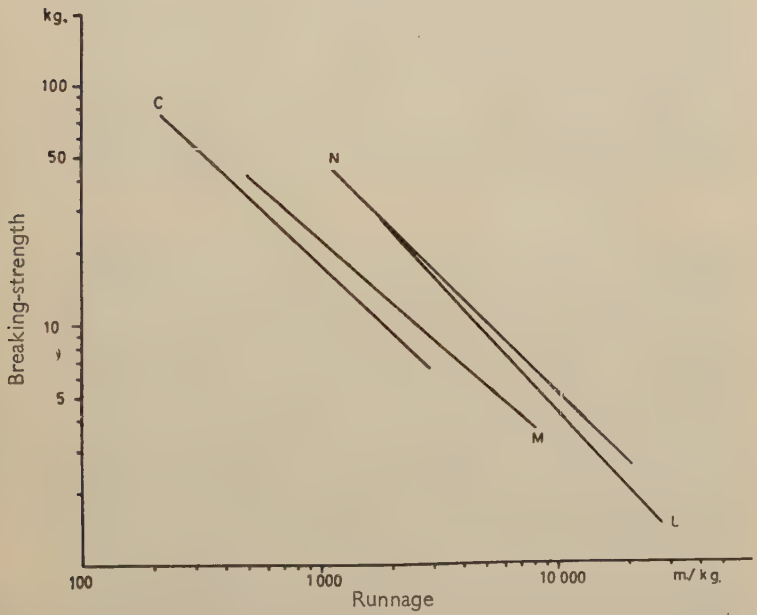


Figure 6. Breaking-strength, wet knotted, of net twines. Nylon gives the best results, followed by flax, cotton and Manryo.
C – cotton ; L – flax ; M – Manryo ; n – nylon.

this as the manufacturers, in their pamphlets, usually mention only the dry breaking-strength. Only knowledge of the strength of the wet knotted twines will allow development of the best possible nets of synthetic fibers. Many losses could be prevented if fishermen knew more about the loss of strength in wet knotted synthetic twines. To introduce man-made fibers successfully in all types of fishing, this fact should be emphasized and net-makers should be made aware that the strength of the wet knotted twines is the true criterion to determine the value of a new material for nets and gear.

9. Extensibility and Elasticity

The extensibility of net twines varies widely. Thinner twines have a lower extensibility than thicker ones. Soft twists with a small number of turns per meter, and soft braided net materials have a smaller extensibility than hard laid or narrow braided materials.

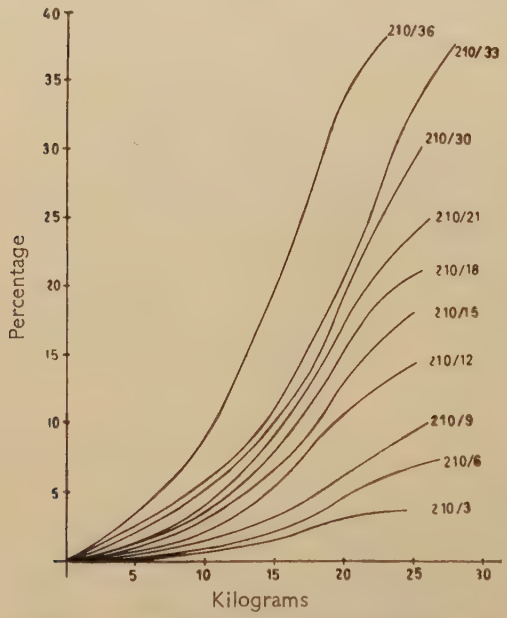


Figure 7. Load-elongation curve of twine made of continuous nylon of different plies.

Some truly synthetic fibers will lose extensibility if spun as high tenacity material. They will also become brittle and the knot strength will be weakened. The breaking extension is of less interest than the load-extension curve (see *Figure 7*). This curve is a graphical representation of the relationship between the change in dimension of the tested twist and the magnitude of the extreme load. The load-elongation curve gives a figure characteristic of the material. For some gear, a high elongation of the net material is profitable, for others a low elongation is better. Fishermen agree that elastic and inelastic stretching of the net, including stretching of knots, is one of the important factors in the selection of fish by gill nets, trawls and seines.

10. Flexibility

Some net twines are pliable, others stiff, i.e., they have a high or low flexibility. It is only the flexibility of the *wet* material

(a)

(b)

(c)

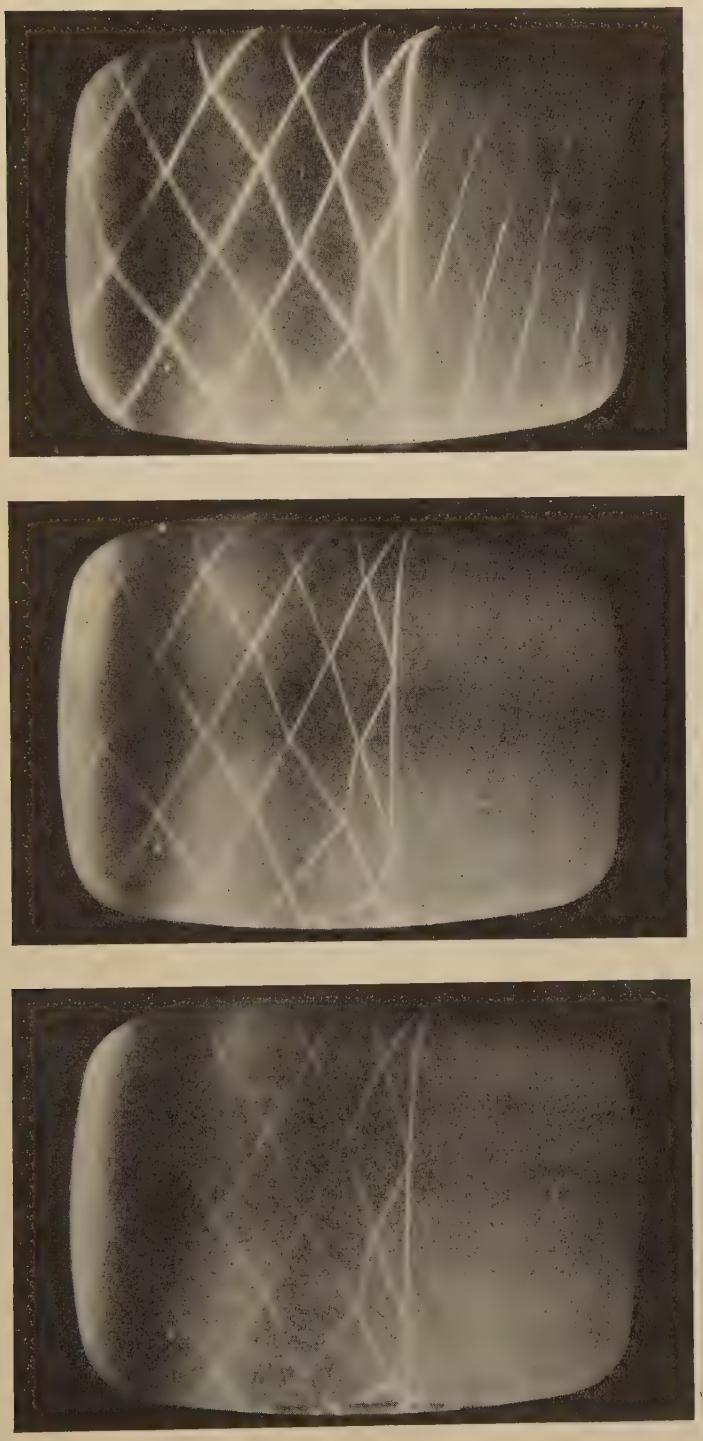


Figure 8. Decreasing visibility of nets made of cotton (*left*) and "Platil" (*right*) with the same diameter, as depth increases and light decreases.
(a) shallow, (b) medium, (c) deep.

that is of interest. The flexibility or smoothness of some twines of truly synthetic fibers can be so high that it is necessary to make them stiffer. Nets with a low flexibility can be more easily handled. On the other hand, soft gill nets have a better efficiency.

11. Visibility

In all passive nets, e.g., fixed or drift nets, in which the fish has to catch itself, a reduced visibility may effect a much bigger catch if there is sunlight. Therefore, these nets are dyed to a color similar to that of the surrounding water. Some man-made fibers are partially translucent in water. Monofilament net materials have a high translucency. The refraction point is near that of glass. This is of great advantage in fishing and should not be eliminated by dyeing (see *Figure 8*). Visibility is a factor of primary importance not only for gill nets, trammel nets and for fishery with hooks, but also for some types of traps.

12. Resistance to Abrasion

Very important for all towed gear is the resistance to abrasion, i.e., against the deterioration of any of its parts by rubbing against another surface. This may be by chafing against sand and pebbles on the sea-bed or by rubbing against the boat sides when the nets are cast, and then lifted, or by the rubbing of one twine against the other. Manufacturing and preparation can influence the resistance to a high degree. For man-made fibers, temperature has a high influence on its resistance to abrasion. Therefore, it is sometimes very difficult to interpret the results of tests for abrasion of different textile fibers. Resistance to abrasion in net twines differs widely (see *Figure 9*).

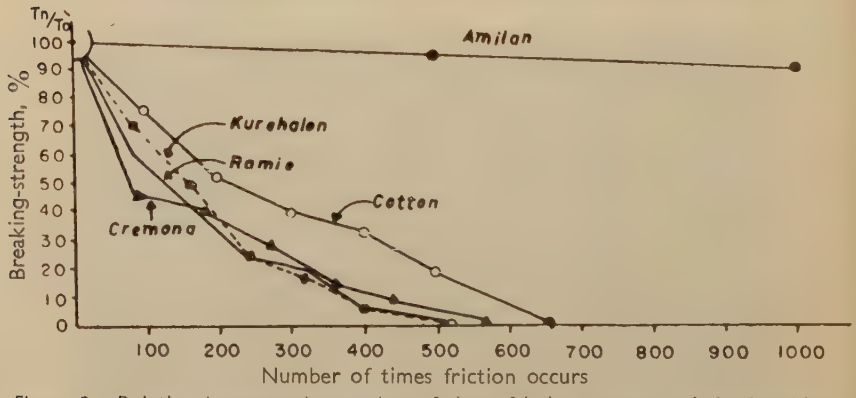


Figure 9. Relation between the number of times friction occurs, and the breaking-strength of thread in wet condition.
(Courtesy H. Miyamoto and H. Takayama 1955)

II. Valuation of the Qualities

The qualities mentioned are all of interest for textile net materials, and it is difficult to say which is the most important. Perhaps the answer will be : none at all, but the price !

Some qualities depend on one another. Low extensibility may go with high breaking-strength but low knot strength. Higher flexibility may be obtained at the expense of breaking-strength.

The best qualities may be a disadvantage in some cases, e.g., some of the truly man-made fibers can be manufactured into twines of a high tenacity, so that thinner twines give the same strength. Herring fishermen cannot take advantage of this for their gill nets. Twines of fine number or high runnage would cut up his fish !

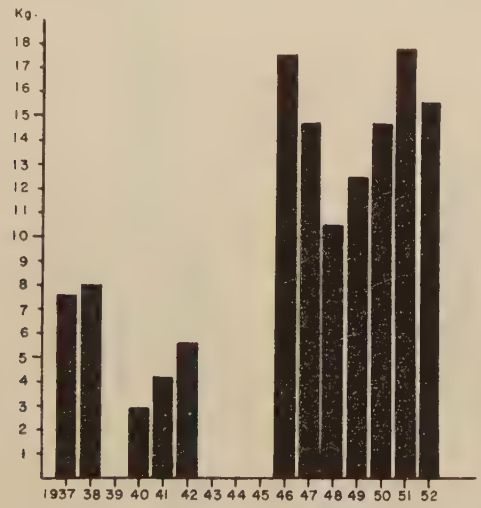


Figure 10. Kilograms of herring to be sold to buy 1 kg. Manila twine in Germany.

Similarly, abrasion can be a limit to the use of such fine twines. Resistance to abrasion becomes lower with increasing fineness of the twines. In the same way the resistance to sunlight can become less with smaller diameters. Low twine resistance to abrasion and sunlight may keep fishermen from using thin twines which would otherwise be strong enough for fishing.

It is difficult to say which material is best. Perhaps one can only say which is the best material available at this moment at any place for a specific gear. The efficiency of a gear can answer whether the material is good or not. The value of the catch and the cost of the gear have to be taken into account. Investigations have been made to show how many fish must be sold to buy a fixed quantity of twines (see *Figure 10*).

Other investigations show comparison of catch with the same gear made of different materials (see *Figure 11*). The results should be compared carefully to decide the rentability of a new synthetic fiber, which will be more expensive than the natural fibers. Many experiments have yet to be performed in this field.

Comparative fishing will give the best answer about the value of a new or old material. But the material with the best qualities is of no value if it is not available, cannot be paid for, or if the catches are small. Natural and man-made fibers present the same difficulties. In some cases gill nets, not treated against rotting, can bring good catches, but they will only last a short time. Rot-proofed gill nets have a lower efficiency, but they can be used for a long time. The fisherman himself has to decide what is the best for his work.

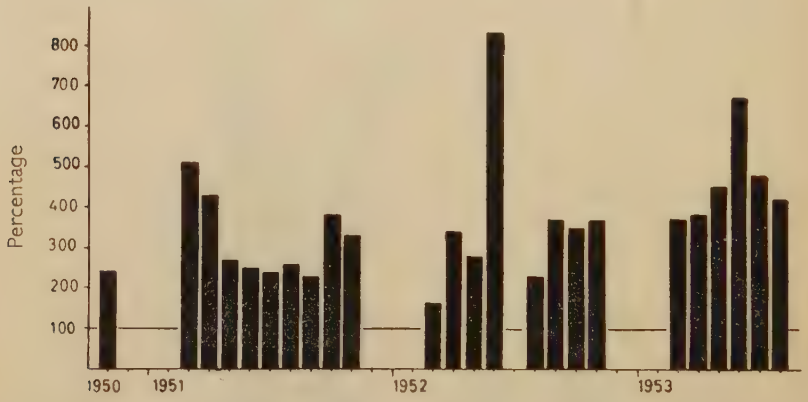


Figure 11. Catch of trout using gill nets made of Perlon monofilament as compared with catch by cotton gill nets. Catch of cotton nets = 100

III. Yarn Numbering Systems

Until about 100 years ago, fishermen in all parts of the world spun their own yarns and knew how to twist twines for their nets. They knew the sort of twine profitable for their gear and did not require numbering systems for twists. The textile industry, however, needs such systems for the production of yarn and twines and the fishing industry has accepted these numbers. Unfortunately, these systems are not yet uniform in all parts of the world and there is some confusion, different systems being used for the same material. This confusion grew as factories or net-makers began to use numbers of their own for net materials of truly manmade fibers[2]. The most important numbering systems are explained as follows :

[2]During the FAO International Fishing Gear Congress 1957 in Hamburg, (*see* p. 216), a working group was formed to find a common agreement on numbering systems for fishing materials.

1. Runnage

A very simple system is the runnage of a net twist or rope. It is based on length of twine per unit weight or mass, i.e. :

meter per kg.	(m./kg.)
yards per lb.	(yds./lb.)
feet per lb.	(ft./lb.)

For strength or other qualities, runnage for the complete twist, etc. (but not for the single yarn), is a good system of comparing the different materials. A higher number means a finer or lighter material ; a lower one, a thicker or heavier twine. In the following, the runnage will be the basis of comparison between different materials and these conversion factors will be needed :

m./kg.	×	0.496	=	yds./lb.
m./kg.	×	1.489	=	ft./lb.
yds./lb.	×	2.015	=	m./kg.
yds./lb.	×	3	=	ft./lb.
ft./lb.	×	0.333	=	yds./lb.
ft./lb.	×	0.672	=	m./kg.

Approximate runnage is spoken of. There may be some differences between the systems of arriving at this number, but small differences are of no importance.

2. Denier

This system is based on weight of twine per unit length. The weight is an old French unit : 1 denier = 0.05 g. The question is, how many deniers (den. or d.) does a fixed length of 450 m. (492 yds.) weigh ? It is the same as the weight in grams of 9,000 m. of twine. This system of numbering has been used for the numeration of silk since ancient times. It is now the one most commonly used for yarns of continuous man-made fibers. A low denier number means a finer yarn, a higher number a coarser one.

The most frequent numbers of denier are 125 and 210, and multiples of these.

3. Other Lengths per Unit Weight Systems

Besides runnage as a length per unit weight system, there are two others, used especially for cotton :

(*a*) the metric number (Nm), using the meter and kilogram system. This system gives the number of meters per 1 g. weight.

(*b*) the English number (Ne) using yards and pounds. This system gives the number of hanks per 1 lb. weight. The length of a hank depends on the material. A hank of cotton has a length of 840 yds., whereas a hank of linen (flax), ramie or hemp is only 300 yds. long.

The metric numbering system, Nm, is generally used for staple, spun or synthetic fibers. For both systems, a higher number means a finer yarn and vice versa.

The conversions can be calculated as follows :

$$\text{Nm} \times 0.591 = \text{Ne for cotton}$$

$$\text{Nm} \times 1.655 = \text{Ne for linen and hemp}$$

$$\frac{9{,}000}{\text{Nm}} = \text{Denier}$$

$$\text{Ne (cotton)} \times 1.683 = \text{Nm}$$

$$\text{Ne (linen)} \times 0.604 = \text{Nm}$$

$$\frac{9{,}000}{\text{denier}} = \text{Nm}$$

4. Diameter *

The numbering system used for monofilaments is the diameter in millimetres or inches. (The circumference is seldom used to measure net materials, but it is a measure for ropes).

There are some other systems and variations of the systems mentioned above for the classification of twines, mostly used in connection with natural fibers.

IV. Yarn and Twine

In most cases, twines are used to make nets, not yarns. For instance, y yarns with the number x may be laid to a twine. It has the number

$$x/y \text{ or } y/x$$

In the first case the number will sometimes be written :

$$x\ s/y$$

where s = spinning count.

For example, y may be 6. The number of the twisted yarns can then be written in different ways :

$x/6$
$x/2 \times 3$ (3 strands of 2 yarns)
$x/2/3$ (3 strands of 2 yarns)
x-23 (3 strands of 2 yarns)
x/6L3 (6 yarns are combined to 3 strands)
x/6 ply R 3 (if the last direction of the twist is a right or S-twist)
x/6 S (if the last direction of the twist is a right or S-twist)
x/6 ply L3 (if the last direction of the twist is a left or Z-twist)
x/6 Z (if the last direction of the twist is a left or Z-twist)

*See p. 210

Sometimes, only one number of the yarn is combined to a twine, and the number of twisted yarns only is used for numeration. This numbering system is of little value as there is no mention of the real number and no control can be made without a sample.

V. Truly Synthetic Fibers Used for Nets

The most important groups of synthetic fibers used for net materials are :

1. Polymide fibers (PA)
2. Polyvinyl chloride fibers (PVC)
3. Polyacrilonitrile fibers (PVY)
4. Polyvinyl alcohol fibers (PVA)
5. Polyester fibers (PE)
6. Copolymer fibers (PVM)
7. Polyethylene fibers

In the following lists some data for twines of the different, truly synthetic, fibers, continuous, staple and monofilament, are given. Data in this field are, however, still incomplete, and further investigations should be carried out as soon as possible.

Another difficulty should be mentioned, that of trade names, the same material sometimes being sold under a different name even in the same country. The same material may have differences in qualities not only induced by processing but also by bonding, stabilizing and treatment. Some approximate data on this score follows.

1. Polyamide Fibers

Universally known net materials such as nylon and Perlon belong to the polyamide fibers (PA). These fibers, though not the oldest group of synthetic fibers used by net-makers, are at present the most important. PA-fibers are offered under different trade names, such as :

Amilan (Japan)	Kenlon (England)	Polan (Poland)
Anzalon (Netherlands)	Knoxlock (Scotland)	Rhodia Nylon (Germany)
Enkalon (Netherlands)	Nylon 66 (U.S.A., etc.)	Rilsan (Brazil, France, Italy)
Forlion (Italy)	Nylock (U.S.A.)	
Grilon (Switzerland)	Perlon (Germany)	Sanderit (Germany)
Kapron (Russia)	Platil (Germany)	Steelon (Poland)

It is impossible here to list all the fibers (staple, continuous and monofilament) belonging to this group.

PA fibers, like all truly synthetic fibers, are never attacked by *microorganisms.*

Resistance to *sunlight* is not very high, but has been improved recently. Bright fibers have a better resistance than delustred (semidull) ones (see *Figure 2*). Twines of continuous and staple

fibers have to be dyed to be protected against the ultraviolet rays of the sun. Simple coloring matters, such as cutch, which is well-known to fishermen, have a better effect than specific dyes. No treatment is necessary for monofilaments.

PA fibers have a high resistance to *thermic influence*. The melting point is above 200°C. (392°F.). Twines of PA fibers may be boiled, but possible shrinkage must be controlled before. Strength can decrease by repeated boiling.

PA fibers have a low *specific gravity* of 1.14, compared with 1.5 to 1.6 for vegetable fibers. This means that the same twine number, based on weight, gives a thicker twine of PA fiber, compared with cotton or other fibers of higher specific gravity.

The *water absorption* of PA fibers is small, the highest being 10%. Yet this small absorption causes some differences in the length and thickness of the wet and dry material. This has to be controlled to meet mesh regulations.

The resistance to *fouling* has already been mentioned in the "Introduction."

PA twines have a high *breaking-strength*. Twines of spun materials are weaker than those of continuous fibers. Wet strength may be 10 to 20% below dry strength. The knot strength can be very small for high tenacity material. The wet knot strength is 30 to 40% weaker than the wet straight twine. Data for the most common twines of nylon are in Table 1.

TABLE 1 — AVERAGE DRY STRENGTH OF NYLON TWINES

Approximate Runnage (m./kg.)	Dry Strength (kg.)
30 000	2
20 000	3
14 000	4
11 000	5
9 000	6
7 800	7
6 600	8
5 800	9
5 200	10
3 400	15
2 400	20
1 800	25
1 600	30
1 150	40
900	50
740	60
620	70
540	80
470	90
420	100

The following tables give particular data for the strength of different net twines made of PA fibers. These are only examples. The data differ slightly from factory to factory.

TABLE 2 — TWINES OF FILAMENT NYLON

Number	Approximate Runnage			Strength						Diameter
				Dry		Wet		Wet knotted		
	m./kg.	yds./lb.	ft./lb.	kg.	lb.	kg.	lb.	kg.	lb.	mm.
210 d 2 ply	20 000	9 970	29 910	3.1	6.8	2.5	5.5	1.8	4.0	—
3	13 400	6 650	19 950	4.5	9.9	3.9	8.6	2.7	6.0	0.28
4	9 900	4 910	14 730	6.2	13.7	5.2	11.5	3.7	8.2	0.37
6	6 900	3 420	10 270	9.2	20.3	7.6	16.8	4.9	10.8	0.45
9	4 350	2 160	6 470	14.2	31.3	11.4	25.1	6.7	14.8	0.60
12	3 300	1 640	4 910	19.1	42.1	15.0	33.1	9.2	20.3	0.67
15	2 600	1 290	3 870	23.3	51.8	18.6	41.0	11.3	24.9	0.78
18	2 300	1 140	3 420	28.7	63.3	22.1	48.7	14.0	30.9	0.84
21	1 890	948	2 810	33.1	73.0	25.7	56.7	15.5	34.2	0.92
24	1 650	820	2 460	36.2	79.8	29.0	63.9	18.0	39.7	0.99
27	1 460	720	2 170	42.0	92.6	34.0	75.0	19.9	43.9	1.05
30	1 350	670	2 010	46.2	101.9	36.7	80.9	21.0	46.3	1.11
33	1 200	595	1 785	49.6	109.4	39.4	86.9	25.2	55.6	1.18
36	1 100	545	1 640	52 0	114.7	42.3	93.3	27.0	59.5	1.25

Table 3 gives data on stabilized spun nylon, which has a higher strength than the common spun nylon.

TABLE 3 — TWINES OF STABILIZED SPUN NYLON

Number	Approximate Runnage			Dry Strength		Diameter	
	m./kg.	yds./lb.	ft./lb.	kg.	lb.	mm.	in.
6	2 500	1 240	3 720	11	25	0.080	0.032
9	1 670	830	2 480	16	36	0.100	0.039
12	1 210	600	1 800	22	49	0.120	0.046
15	905	450	1 350	28	62	0.130	0.052
18	745	370	1 120	33	73	0.140	0.056
21	645	320	960	39	86	0.150	0.060
24	565	280	840	44	97	0.170	0.065
27	505	250	740	49	108	0.175	0.069
30	445	220	670	55	121	0.190	0.073
36	370	185	555	65	144	0.200	0.080
42	320	160	470	76	168	0.220	0.086
48	280	140	410	87	192	0.230	0.092
54	245	122	365	98	216	0.240	0.093
60	220	109	328	111	244	0.260	0.103
72	183	91	272	131	288	0.290	0.113
86	155	77	232	153	337	0.320	0.128
96	135	67	202	175	386	0.330	0.130
108	121	60	180	197	434	0.360	0.140
120	107	53	159	268	590	0.370	0.145
132	97	48	145	286	630	0.400	0.156
156	85	42	125	324	715	0.440	0.172
192	67	33	100	345	870	0.480	0.188
330	38	19	56	617	1 360	0.640	0.250

Twines made of filament fibers have a higher strength than those of staple fibers. Sometimes, the continuous fibers produce difficulties in netting ; twines are too slippery, the knots may be

loosened, and meshes are not constant. To combine the strength of the twines of filament fibers with the constant knots of the spun materials, mixed twines from both groups were made.

Table 4 gives some data on the strength of these mixed twines.

TABLE 4 — TWINES OF MIXED NYLON FIBERS

Number	Approximate Runnage			Dry Strength	
	m./kg.	yds./lb.	ft./lb.	kg.	lb.
12	1 100	550	1 638	35	78
15	860	425	1 275	42	93
21	590	295	880	59	130
30	540	270	620	70	155
36	360	180	540	94	208
48	270	130	395	119	263
60	200	100	300	144	318
72	180	90	265	172	378
96	130	65	190	340	748
108	110	55	160	253	557

These are examples of the strength of net twines made of continuous staple and mixed nylon fibers. Nylon monafilaments are offered under the registered name Tynex. Table 5 gives data for minimum and average break load in kilograms and pounds.

TABLE 5 — NYLON MONOFILAMENT

Diameter		Tynex 2				Tynex 3				Tynex 4			
		Minimum		Average		Minimum		Average		Minimum		Average	
mm.	in.	kg.	lb.	kg.	lb.	kg.	lb.	kg.	lb.	kg.	lb.	kg.	lb.
0.15	0.006									0.9	2.0		
0.18	0.007									1.4	3.0		
0.20	0.008	1.6	3.5	1.7	3.7					1.6	3.5	1.9	4.2
0.23	0.009	1.8	4.0	2.0	4.5					1.9	4.2	2.5	5.5
0.25	0.010	2.0	4.5	2.5	5.5					2.4	5.2	3.0	6.5
0.28	0.011	2.4	5.2	2.8	6.2					2.8	6.2	3.5	7.7
0.30	0.012	2.8	6.2	3.4	7.6					3.3	7.2	4.1	9.1
0.33	0.013	3.3	7.2	3.9	8.7					3.9	8.6	4.9	10.7
0.36	0.014	3.7	8.1	4.4	9.7					4.5	10.0	5.5	12.2
0.38	0.015	4.1	9.0	5.2	11.5					5.2	11.5	6.3	13.8
0.43	0.017	5.3	11.7	6.6	14.5					6.8	15.0	7.8	17.5
0.48	0.019	6.6	14.6	8.2	18.0					8.5	18.7	10.0	22.0
0.53	0.021	8.0	17.6	9.9	21.7					10.4	23.0	12.0	26.5
0.58	0.023	9.5	21.0	11.8	26.0					12.3	27.0	14.3	31.5
0.63	0.025									14.1	31.0	16.8	37.0
0.71	0.028					12.5	27.5	14.5	32.0	18.2	40.0	20.9	46.0
0.81	0.032					16.3	36.0	19.1	42.0	23.6	52.0	27.2	60.0
0.91	0.036					20.4	45.0	24.1	53.0	30.0	66.0	34.5	76.0
1.02	0.040					25.4	56.0	30.0	66.0	37.0	81.5	42.4	93.5
1.14	0.045					32.2	71.0	37.7	83.0	46.8	103.0	53.6	118.0
1.27	0.050					39.7	87.5	46.5	102.4	57.7	127.0	65.8	145.0
1.40	0.055					48.1	106.0	56.1	123.5	69.5	153.0	79.9	178.0
1.52	0.060					52.2	126.9	66.7	147.0	81.7	180.0	94.4	208.0

Perlon is another important PA fiber. In contrast to nylon, more Perlon twines made of staple are used in fishing than filament fibers. The strength of Perlon twines is shown in the following tables :

TABLE 6 — TWINES OF PERLON STAPLE

Nm 20 Ne 12	Approximate Runnage			Strength					
				Dry		Wet		Wet knotted	
	m./kg.	yds./lb.	ft./lb.	kg.	lb.	kg.	lb.	kg.	lb.
Nm 20/6	2 900	1 440	4 320	11.1	24.5	7.9	17.4	5.9	13.0
20/9	1 950	970	2 400	16.2	35.7	12.5	27.6	9.4	20.7
20/12	1 400	695	2 090	19.5	43.0	15.5	34.2	11.6	25.6
20/15	1 100	545	1 640	23.5	51.8	17.6	38.8	13.2	29.1
20/18	960	465	1 400	30.8	67.9	24.0	52.9	18.0	39.7
20/21	830	410	1 240	32.7	72.1	30.3	66.8	22.7	50.1
20/24	700	345	1 040	38.4	84.7	33.6	74.1	25.2	55.6
20/27	620	310	925	43.2	95.3	36.7	80.9	27.5	60.6
20/30	540	270	805	48.0	105.8	40.0	88.2	30.0	66.2
20/36	470	235	700	56.0	123.5	50.0	102.5	37.5	82.7
Nm 50 Ne 30									
Nm 50/6	7 250	3 600	10 790	4.0	8.8	3.0	6.6	2.2	4.9
50/9	5 000	2 480	7 460	7.0	15.4	4.6	10.1	3.5	7.7
50/12	3 600	1 790	5 360	9.3	20.5	6.1	13.5	4.6	10.1
50/15	2 900	1 440	4 320	11.5	25.4	7.5	16.5	5.6	12.3
50/18	2 400	1 190	3 570	14.0	30.9	10.6	23.4	7.8	17.2
50/21	2 000	990	2 980	15.0	33.1	11.0	24.3	8.3	18.3
50/24	1 800	895	2 680	16.0	35.3	12.5	27.6	9.4	20.7
50/36	1 200	595	1 785	22.6	49.8	18.7	41.2	13.9	30.6

TABLE 7 — TWINES OF PERLON FILAMENT

Number	Approximate Runnage			Strength					
				Dry		Wet		Wet knotted	
	m./kg.	yds./lb.	ft./lb.	kg.	lb.	kg.	lb.	kg.	lb.
85 den./3	35 000	17 400	51 100	1.7	3.7	1.5	3.3	1.1	2.4
/4	23 000	11 400	34 200	2.2	4.9	2.0	4.4	1.5	3.3
/6	15 500	7 400	22 300	3.9	8.6	3.0	6.6	2.3	5.1
/8	11 000	5 500	16 400	4.9	10.8	4.0	8.8	3.0	6.6
240 den./6	5 750	2 850	8 550	5.6	12.3	4.9	10.8	4.2	9.3
/9	3 520	1 750	5 250	9.2	20.3	8.0	17.6	6.2	13.7
/12	2 620	1 300	3 900	11.3	24.9	9.3	20.5	7.3	16.1

As regards strength, Perlon, in the form of monafilaments, differs from one factory to another since strength decreases with the increase of softness or flexibility.

TABLE 8 — PERLON MONOFILAMENT WITH HIGH FLEXIBILITY

Diameter		Approximate Runnage			Strength						Flexibility
					Dry		Wet		Wet knotted		
mm.	in.	m./kg.	yds./lb.	ft./lb.	kg.	lb.	kg.	lb.	kg.	lb.	
0.15	0.006	35 000	17 350	52 000	0.9	2.0	0.85	1.87	0.6	1.3	2
0.20	0.008	22 500	11 150	33 500	1.4	3.1	1.12	2.47	0.8	1.8	3
0.30	0.012	10 300	5 100	15 350	3.1	6.7	2.80	6.2	1.8	4.0	14
0.40		6 000	3 000	8 950	5.4	11.8	4.50	9.9	3.2	7.1	26
0.50		3 900	1 950	5 800	8.3	18.3	7.40	16.3	4.3	9.5	56
0.60		2 750	1 350	4 100	11.9	26.2	12.70	28.0	6.5	14.3	117
0.70		2 050	1 020	3 050	16.0	35.3	14.70	32.4	7.5	16.5	136
0.80		1 600	795	2 380	20.6	45.4	16.80	37.0	11.5	25.4	169
0.90		1 280	635	1 905	25.5	56.2	18.80	41.5	12.9	28.4	220
1.00		1 000	495	1 490	31.4	64.2	25.90	57.1	13.7	30.2	299

It should be added, that PA filament fibers are plaited if a stronger material is needed for heavier gear. The strength of this plaited material differs widely, according to its manufacture.

TABLE 9 — PLAITED PERLON FILAMENT

Approximate Runnage			Strength			
			Dry		Wet	
m./kg.	yds./lb.	ft./lb.	kg.	lb.	kg.	lb.
1 440	715	2 145	40	88	34	75
1 270	630	1 890	51	112	43	85
1 040	515	1 550	55	121	47	104
840	415	1 250	74	163	62	137
690	340	1 025	83	183	71	157
650	325	970	101	223	81	179
500	250	745	110	243	94	207
450	225	670	130	287	110	243
400	200	595	151	333	128	282
350	175	520	160	353	136	300
300	150	445	190	419	162	357
265	130	395	200	441	170	375
190	95	280	280	612	238	525

The *extensibility* of the twines made of PA fibers also varies greatly. The stretching qualities differ considerably according to the kinds of thread. If compared with natural fibers, the difference may be important. Twines of spun fibers have a higher extension than those made of filament. Twines of high tenacity material have a low extension, but they will become brittle.

On the whole, the extension as well as the elasticity of twines made of PA fibers is higher than in natural fibers, such as bast fibers. Because of this, the twines of PA fibers are more easily able to eliminate kinetic energy, i.e., the influence of a sudden load.

But, in most cases, the elongation of all truly synthetic fibers is, to a certain extent, technically adjustable. Therefore, no rule of common validity is available for twines made of PA fibers.

The *flexibility* of such twines is very high. They will become very soft, if wet. Treatment to stiffen them may be necessary in some cases to give better handling and to effect a better shape of the nets in a current.

The net materials of PA fibers have a low *visibility*. This not only concerns monofilaments which have a high translucency. The color of the net materials is only important in contrast to its surroundings.

The resistance of synthetic fibers of the PA group to *abrasion* is very high. Twines of spun fibers are less resistant than those of continuous fibers. However, their resistance is higher than that, for instance, of cotton twines. *Figure 12* shows the influence

(Courtesy G.Klust)

Figure 12. Effect of equal friction on Manila (*above*) and plaited Perlon (*below*).

of the same amount of abrasion on a line made of manila, and on a plaited Perlon line. In the former, one strand is broken off, and more than 60% of the strength is lost ; in the latter, the line merely becomes rough, and only 20% of the original strength is lost.

The resistance to abrasion is related to the manufacture of the twine. Resistance is also appreciably affected by the conditions under which the abrasion occurs, and by the nature of abrasion. In most cases, the resistance of PA twines is higher in a dry rather than a wet condition. It should be noted that, by abrasion, PA fibers will get a rough, woolly surface. A fisherman knows by experience that this means an enormous loss of strength for natural fibers. This is not always the case with PA fiber twines, the loss of strength being lower, the wider the diameter.

2. *Polyvinyl Chloride Fibers*

Polyvinyl chloride is a widely known plastic (PVC). The fibers of this group were the first man-made fibers produced commercially. PVC fibers were also the first truly synthetic fibers to be used for fishing nets. In 1936, the first fishing gear, namely traps, braided with PVC twines, were tested in Germany.

The qualities of these twines were not so good as those made of cotton, but twines of PVC fibers were the first fibers resistant to rotting that were available for netmaking. A revolution in fishing took place and all other qualities were at first neglected. Since the beginning of fishing in ancient times, fishermen have sought to prevent the microbiological damaging of nets made of natural fibers. Rotproofed nets are important for the rentability of the fishery. Other synthetic fibers with this outstanding charactistic were later introduced into fishing and, as some of them had better qualities for making nets, the PVC fibers lost their first place. PeCe, PCU and Rhovyl are in the PVC fiber group. Only PeCe fibers had some importance in fishing for the reasons mentioned above.

There have been twines of PeCe staple fibers, continuous and mixed yarns. Twines of PeCe have a medium resistance to sunlight. Twines of PCU and Rhovyl have the highest resistance to ultraviolet rays (see *Figure 2*). This is because of a difference in manufacture of PeCe fibers, and those of PCU or Rhovyl. On the other hand, PVC fibers have a low *thermic quality*. They are thermoplastics. As for natural fibers, their *specific gravity*, 1.44, is somewhat less. The *dry strength is the same as the wet breaking-strength*. It is because of their low breaking-strength and low resistance to *abrasion*, that PVC fibers lost their importance in Europe.

In recent years, two new kinds of PVC fibers have been introduced in Japan — Teviron and Envilon. Teviron yarn is produced as a filament and staple. It has a higher strength, independent of humidity, than the oldest fibers of this group : PeCe. Specific gravity is 1.39. Teviron and Envilon are thermoplastics with great resistance to sunlight, and are the cheapest synthetic fibers produced in Japan.

3. *Polyacrylonitrile Fibers*

Polyacrylonitrile fibers (PVY), such as Orlon (U.S.A.), PAN (Germany), or Dralon (Germany), are known in hosiery and textile manufacture all over the world.

However, it seems that PVY fibers have not yet been produced as net twines. The main reason for this is their high price. Their breaking-strength is not so high as that of PA fibers with the same number of plies. Their wet strength is only 10% lower than the dry breaking-strength. Their resistance to sunlight is very high and their resistance to abrasion is low, and not greatly different from that of PVC twines. There is no information on the usefulness of PVY twines for fish nets.

4. *Polyvinyl Alcohol Fibers*

The first fibers of the polyvinyl alcohol group (PVA) were produced in Europe, and the first patent was taken out in Germany, in 1931. But it was through Japanese research that PVA fibers became well-known to netmakers, and effected a remarkable development in the fishery of that country. The name of these PVA fibers is vinylon. Today there are many trade names, such as Cremona, Kuralon, Manryo, Newlon, and Kanebian. Sometimes the brand name for the same material differs from country to country.

Most twines are made of staple fibers, but there are also continuous and monofilament yarns and twines.

These fibers have two important characteristics. Firstly, a low *melting point*. Some types — the thermoplastics — begin to soften at 40°C. (104°F.) Other kinds, however, may have a higher softening and melting point, e.g., Kuralon and Manryo, at 60°C. (140°F.) or over. As the melting point differs so widely, testing is necessary in each case. Secondly, PVA fibers have a special *chemical* characteristic : they can be damaged by cutch. Some fishermen dye nets of synthetic fibers with this kind of tar. The reason is not to preserve them against rotting, but to have bigger catches by means of colored nets. Dyed with cutch, PVA twines will shrink, become hard, and lose their strength.

All synthetic fibers can be dissolved by chemicals, but most of these are not used by fishermen. Phenol will bring about the dissolution of PA fibers, and tar that of PVC fibers. PVA twines may be tarred. This is highly desirable, as they are strengthened by tar. Their *specific gravity* lies between 1.26 and 1.30, i.e., between that of PA and vegetable fibers. PVA fibers have a high resistance to sunlight.

Table 10 gives an example of breaking-strength, for Manryo spun twine. Only spun yarn is at present available.

TABLE 10 — MANRYO SPUN TWINE

Nm 34 Ne 20 (*ply*)	Approximate Runnage			Straight Twine				Strength			
				Dry		Wet		Dry (single)		Wet knotted	
	m./kg.	yds./lb.	ft./lb.	kg.	lb.	kg.	lb.	kg.	lb.	kg.	lb.
4	7 250	3 600	10 800	4.3	9.5	3.6	7.9	2.0	4.4	1.8	4.0
6	4 850	2 410	7 230	6 9	15.2	5.7	12.6	2.9	6.4	2.6	5.7
9	3 230	1 600	4 800	10.2	22.5	8.3	18.3	4.1	9.0	3.6	7.9
12	2 420	1 200	3 600	13.3	29.3	10.8	23 8	5.2	11.5	4.6	10.1
15	1 940	960	2 880	15.8	34.8	13.0	28.7	6.6	14.6	5.6	12.3
18	1 610	780	2 340	18.3	40.4	15.0	33.1	7.6	16.8	6.7	14.8
21	1 380	680	2 040	20.5	45.2	17.6	38.8	8.9	19.6	7.5	16.5
24	1 210	600	1 800	22.5	49.6	18.7	41.2	10.0	22.1	8.6	19.0
30	970	480	1 440	27.0	59.5	22.9	50.5	12.1	26.7	10.8	23.8
36	810	400	1 200	30.5	67.3	25.2	55.6	13.9	30.6	12.2	26.9
45	645	320	960	36.5	80.5	28.4	62.6	16.5	36.4	14.5	32.0
60	485	240	720	42.4	93.5	36.2	79.8	21.8	48.1	18.4	40.6
75	385	190	570	48.7	107.4	41.9	92.4	24.6	54.2	20.9	46.1

The dry, straight Kuralon twine is over three times as strong as cotton twine of the same size and in the same condition and, even when wet, is twice as strong ; but when knotted and in the water, as in all twine being used in fishing gear, the Kuralon twine has the same strength as cotton. The staple nylon twine, when knotted, is stronger, wet or dry, than either Kuralon or cotton (Carrothers, 1956).

Twines of PVA fibers seem to be the most varying in quality of all truly synthetic net materials mentioned in this paper. On the other hand, PVA fibers are said to be, or to become, very cheap and their price compared with that of natural fibers is not too high. It may be that PVA fibers will become more important for fishing in other countries besides Japan in the near future.

PVA twines have a low knot strength. This factor is unimportant if the twines are used for knotless nets. The knotless net is the most modern form of netmaking, and has many advantages. It might be the basis for the utilization of cheap synthetic twines, which lose 50% or more of their strength in knots.

A special twine for nets is manufactured under the trade name of Marlon. This is a mixture of nylon and vinylon. A filament yarn is combined with a spun yarn. Untreated fibers sometimes slip and may cause the knots to slip off. The high strength of nylon is preserved by this combination, without any danger of the knots slipping.

5. Polyester Fibers

Polyester fibers (PE), have various registered trade names, such as Terylene (U.K.), Puffin (U.K.), Dacron (U.S.A.), Trevira and Diolen (Germany). This group is beginning to come into use for fish nets.

Like all truly synthetic fibers, it has a complete *resistance to rot.* The resistance of PE fibers to sunlight is higher than that of natural fibers or PA fibers. No disadvantage of *thermic influence* is known. Twine of PE fibers may be boiled. A small possible shrinkage should be controlled before.

The *specific gravity* (1.38) is nearly as high as that of true silk (1.36). The *water absorption* of PE fibers is lower than that of PA fibers. Twines of PE fibers have a high breaking-strength. The dry strength and the wet strength are the same for all practical purposes.

Tables 11 and 12 give some data for filament and spun twines.

The strength is diminished about 40% by knotting. The extensibility is rather small. This may be advantageous. On the other hand, low extensibility can cause difficulties in connection with sudden load. The resistance to abrasion is not so high as that of twines made of PA fibers.

TABLE 11 — TERYLENE TWINES

Denier	Ply	Approximate Runnage			Strength	
		m./kg.	yds./lb.	ft./lb.	kg.	lb.
125	6	12 000	5 950	17 850	4.5	9.9
	9	8 000	3 970	11 910	6.8	15.0
	12	6 000	3 000	9 000	9.0	19.8
	15	4 800	2 380	7 140	11.2	24.7
	18	4 000	1 980	5 940	13.5	29.8
	21	3 524	1 750	5 250	15.8	34.8
	24	3 000	1 490	4 470	18.0	39.7
	27	2 666	1 320	3 960	20.2	44.5
	30	2 400	1 190	3 570	22.5	49.6
250	6	6 000	3 000	9 000	9.0	19.8
	9	4 000	1 980	5 940	13.5	29.8
	12	3 000	1 490	4 470	18.0	39.7
	15	2 400	1 190	3 570	22 5	49.6
	18	2 000	990	2 970	27.0	59.5
	21	1 726	875	2 625	31.5	69.5
	24	1 500	745	2 235	36 0	79.5
	27	1 333	660	1 980	40.5	89.3
	30	1 200	595	1 785	45.0	99.2
	34/3	270	135	405	116.0	256 0
	49/3	195	97	291	182.0	401.0

TABLE 12 — STABILIZED SPUN DACRON

Number	Approximate Runnage			Strength		Diameter	
	m./kg.	yds./lb.	ft./lb.	kg.	lb.	mm.	in.
6	1 815	901	2 704	20	44	0.080	0.030
9	1 220	605	1 816	32	70	0.100	0.038
12	905	449	1 348	36	80	0.110	0.045
15	725	360	1 080	50	110	0.130	0.052
18	669	332	996	63	138	0.150	0.058
21	515	256	768	68	150	0.160	0.062
24	451	224	672	77	170	0.170	0.065
27	397	197	592	86	190	0.183	0.072
30	361	179	536	95	210	0.188	0.074
36	298	148	445	110	240	0.200	0.080
42	252	125	376	120	260	0.216	0.085
48	220	109	328	135	300	0.224	0.088
54	198	98	293	155	345	0.240	0.093
60	171	85	254	180	400	0.260	0.101
72	147	73	218	225	495	0.290	0.114
84	125	62	186	245	540	0.310	0.121
96	109	54	162	270	595	0.340	0.134
108	97	48	144	290	640	0.360	0.140
120	89	44	133	315	700	0.370	0.145
132	81	40	121	335	740	0.400	0.156
156	71	35	104	380	840	0.440	0.172
192	56	28	84	465	1 020	0.480	0.188
330	32	16	47	725	1 600	0.640	0.250

6. *Copolymer Fibers*

The copolymers of vinyl chloride, vinyl acetate, vinylidene chloride, and so on, form a special group of fibers. The first copolymers of vinyl chloride and vinylidene chloride were produced in the United States of America. Japan has today an important

output of these interesting fibers. Some of them are manufactured for making fish nets. They are also sold under trade names such as Saran, Kurehalon or Krehalon.

Saran has a high *resistance* to destructive weather influence (see *Figure 13*). Exposure to the ultraviolet rays of the sun does

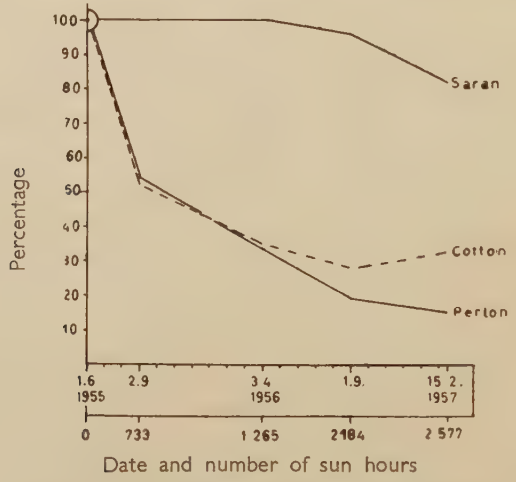


Figure 13. Decrease in strength of different net twines, caused by sunlight.

not seriously reduce the breaking-strength. *Water absorption* is extremely low. Nets made of Saran do not become heavier when wet and no change of length or thickness of the twines can be noticed. The softening point is between 140°C. and 160°C. (290°F. and 320°F.). Testing is necessary before boiling.

As to *thermic qualities*, the melting points may vary in material from one factory to another. Saran has a high chemical resistance to almost all acids and alkalies. It is the only synthetic fiber heavier than the natural fibers.

The *specific gravity* of Saran, at 1.7, is approximately 10% higher than that of cotton. This means a very good shape of the net in the water, because it is not swayed by tidal currents and, further, a higher sinking speed means easier operation.

There are no differences in dry strength or wet strength. The breaking-strength of Saran is not so good as that of some other natural and man-made fibers. Monofilaments and multifilaments are used for net manufacture. The following data for breaking-strength are the result of experiments with monofilaments of various diameters (German production).

The strength will be diminished about 40% by knotting.

There is no loss of strength if Saran multifilaments are used for knotless nets. The *extensibility* of Saran monofilaments lies between 20 and 30%. Table 13 gives some data of *flexibility* or softness.

Saran monofilaments are not so hard or stiff as PA monofilaments of the same diameter. Table 14 shows similar data for Livlon twine.

Resistance to *abrasion* is good. This quality decreases with increasing temperature.

In water, Saran monofilaments are resilient and of high resistance to abrasion. Saran can be mixed with nylon in different degrees. Livlon and Saran N are trade names for twisted yarn of a blend of Saran and nylon.

TABLE 13 — SARAN MONOFILAMENT

Diameter mm.	Denier (about)	Approximate Runnage			Strength				Flexibility
					Straight		Single knot		
		m./kg.	yd./lb.	ft./lb.	kg.	lb.	kg.	lb.	
0.13	214	42 000	20 840	62 520	0.42	0.93			
0.18	410	21 800	10 817	32 541	0.82	1.81			
0.20	665	18 400	9 130	27 390	0.94	2.10			
0.23	865	13 500	6 699	20 097	1.16	2.60			5
0.25	1 280	10 400	5 160	15 480	1.38	3.00	1.0	2.2	8
0.30	1 900	7 000	4 373	10 419	1.90	4.20	1.1	2.4	10
0.38	3 450	4 700	2 332	6 996	3.16	7.00	2.3	5.1	28
0.50		2 800	1 389	4 167	5.40	11.90	2.9	6.4	38
0.64		1 820	903	2 709	8.40	18.50	5.4	11.9	
0.75		1 200	595	1 785	11.40	25.10			
0.89		840	417	1 251	15.00	33.10			
1.00		700	347	1 041	16.30	35.90	10.1	22.3	
1.14		530	263	789	20.00	44.10			
1.25		450	223	669	21.80	48.10			
1.50		250	124	372	23.50	51.80			

TABLE 14 — LIVLON TWINE

Number	Ply	Momme* per fm.	Approximate Runnage			Strength			
			m./kg.	yds./lb.	ft./lb.	Dry		Wet	
						kg.	lb.	kg.	lb.
MS- 1	4	0.053	7 661	3 801	11 403	3.68	8.1	3.05	6.7
MS- 2	6	0.087	4 644	2 304	6 912	5.00	11.0	4.58	10.1
MS- 3	9	0.143	2 825	1 402	4 206	7.41	16.3	6.81	15.0
MS- 4	12	0.176	2 312	1 147	3 441	9.70	21.4	8.97	19.8
MS- 5	15	0.232	1 754	870	2 610	12.39	27.3	11.14	24.6
MS- 6	18	0.264	1 542	765	2 295	15.51	34.2	13.85	30.5
MS- 7	21	0.320	1 272	631	1 893	16.59	36.6	14.86	32.8
MS- 8	24	0.356	1 143	567	1 701	18.10	39.9	16.51	36.4
MS-10	30	—	—	—	—	23.29	51.4	21.14	46.6
MS-12	36	—	—	—	—	27.94	61.6	25.27	55.7

* 1 momme 3.75 g.

Two mixtures of Saran N are offered : Saran N Super with 36% Saran and 64% nylon, and Saran N General, with 63% Saran and 37% nylon.

TABLE 15 — SARAN N GENERAL

Number	Approximate Runnage			Strength						Diameter	Flexibility
				Dry		Wet		Wet knotted		mm.	
	m./kg.	yds./lb.	ft./lb.	kg.	lb.	kg.	lb.	kg.	lb.		
12	2 500	1 240	3 720	10.4	22.9	8.3	18.3	5.8	12 8	0.69	5
15	1 800	890	2 670	12.4	26.7	10.2	22.5	6.8	15.0	0.82	8
18	1 600	790	2 370	15.2	33.5	12.2	26.9	8.0	17.6	0.92	8
24	1 200	600	1 800	20.0	44.1	16.7	36.8	10.8	23.8	0.98	10

Nets made of this combined twine are not as hard as those made of Saran only; but no preparations are necessary to get higher stiffness as is sometimes the case with fishing gear of PA fibers.

7. Polyethylene Fibers

The most recent group of synthetic fibers known in fishery are polyethylene fibers. The single tests carried out so far give little information on their applicability to fishing. These fibers, mostly monofilaments, are sold under such trade names as Polythene, Courlene, Courlene × 3.

Polyethylene fibers have a new property, in so far as their specific gravity is below 1 (0.93 - 0.96), and they are therefore the lightest fibers available at the present time. What effect this may have on fishing cannot yet be anticipated. However, it must be remembered that these fibers can soften at a temperature of below 100°C. (212°F.).

VI. Summary and Conclusion

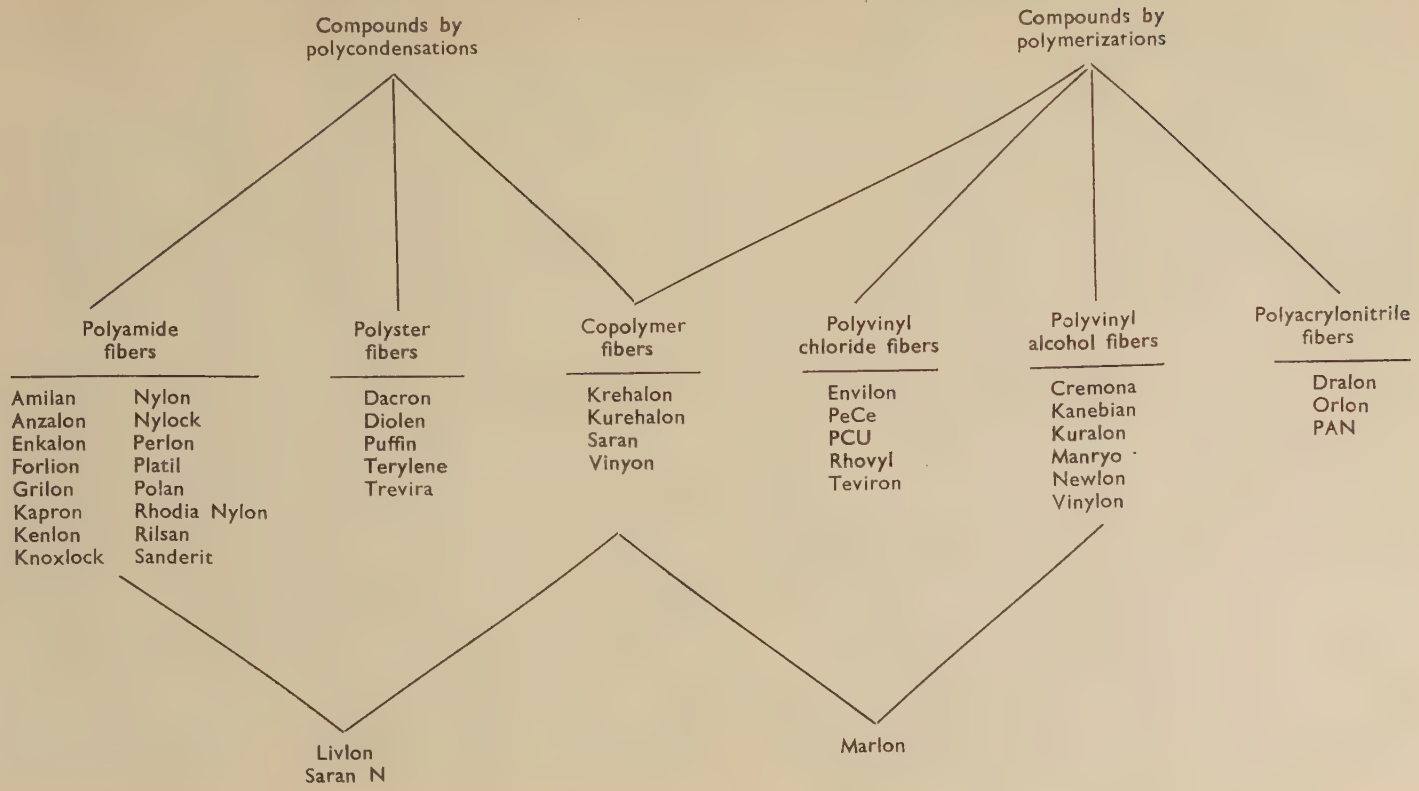
There are at present seven groups of truly synthetic fibers used for net materials (*see* diagram opposite).

Today, only the groups of polyamide and polyvinyl alcohol fibers are of high value to fishermen. The groups of polyester fibers and copolymer fibers may be of general interest in the future. Yet, at the present moment, only two fibers have a world wide importance for fishermen: Nylon/Perlon and, in some areas, Manryo/Kuralon.

Qualities of importance to fish nets are:

resistance to rotting
resistance to sunlight
thermic quality
resistance to chemicals
specific gravity
resistance to water
resistance to fouling
breaking strength, specially wet with single knots extensibility and elasticity
flexibility
visibility
resistance to abrasion

Diagram Showing the Present Groups of Truly Synthetic Fibers



Not much is known yet about these qualities, even for the small number of synthetic fibers used at present for nets by fishermen. Further research should be carried out as soon as possible.

The main difficulty is that the qualities of net twines of synthetic fibers vary not only because of the differences between the different fibers due to manufacture, but even more because of the diverse processing procedures in spinning, twisting and plaiting.

On the other hand, apart from the different requirements of fishermen, the qualities of the net materials can vary with every fishing gear and every fishing method. It cannot be said that this or that is the best synthetic fiber for net-making. Only the best man-made fiber for a special gear under specific conditions in a specific area can be determined.

In many cases, the worth of a new fiber for fishing can only be found by experiments with fishing gear. Comparative fishing alone can demonstrate whether the efficiency and the rentability of a new fiber is higher, on the whole, than those of the ones used before. Some qualities of twine can be controlled in laboratories.[3] But there are other factors to be considered for all gear made of new materials, namely:

quantity of the catches made
durability
convenience of handling

These qualities can only be determined by commercial fishing experiments with gear made of new fibers. The practical experiment will always be the best.

Tex System[4]

A new numbering system recommended by the International Standards Organization Conference is the Tex system. The value N is based on weight or mass in grams per unit length in km. The question is, how many grams does a fixed length of 1 km. weigh?

Conversions can be done in the following way:

$$\text{Tex} = \frac{1{,}000}{\text{Nm}} = \frac{590.5}{\text{Ne (Cotton)}} = \frac{1{,}654}{\text{Ne (Linen)}} = 0.111 \text{ den.}$$

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[3]During the FAO International Fishing Gear Congress 1957 in Hamburg, Western Germany, a working party was formed to propose test methods suitable for fishery.

[4]It is regretted that this paragraph was received too late to be included in the text before going to press. It should be inserted in Chapter III as item 4 and the present paragraph 4 would then become 5.

TILAPIA IN ANCIENT EGYPT*

"All Egyptians in the Nile Delta possess a net with which, during the day, they fish....."

"The Egyptians eat fish, some raw and sun-dried, others conserved in brine."
Herodotus, 484-425 B.C., Book II (95) and (77)

Two reviews by the author in previous issues of this *Bulletin* [VIII(1) : 1-33 ; X(1) : 1-24], have dealt with the culture of tilapia in ponds — a subject that has excited much interest in equatorial and sub-tropical regions. These articles indicated that the culture of tilapia, now in operation in the hot areas of the world, was of quite recent origin. For example, the beginning of pond culture of *T. mossambica* was attributed to the Fisheries Service of the Netherlands East Indies, for work carried out in Java in 1939. Even earlier, in 1937, some attempts had been made in the Belgian Congo and, antedating even these records, were the trials of both *T. nigra* and *T. melanopleura*, carried out in Kenya in 1924. From the historical standpoint it appeared, therefore, that these tests in Kenya marked the beginning of tilapia culture. A study of the bas reliefs and inscriptions on the monuments of Ancient Egypt, especially those to be found at the Louvre in Paris, opens up new horizons and enables us to attribute to the Ancient Egyptians priority not only in the pond culture of tilapia, but also for pond culture in general.

Tilapia was well-known in Egypt in 3,000 B.C. ; it is often represented in bas reliefs, so beautifully and exactly designed that the species can clearly be determined — without doubt *T. nilotica*, easily recognizable by the slightly rounded caudal fin. This species is still very abundant in the Nile.

The *T. nilotica* of Ancient Egypt was called " Inet, " and was a sacred fish, like the " Aha " or *Lates niloticus* (Nile perch). According to Egyptologists, the Inet symbolized the hope for rebirth after death. Many articles have been written on the symbolical significance of tilapia. The Inet was closely connected with the goddess Hathor. The color turquoise was assigned to the tilapia, and it was painted this color in the bas reliefs ; it was forbidden to eat this fish on the 28th day of the fourth month of the Akhit because " the inhabitants of Mendés at death are transformed into the fish Inet. "

But to return to fisheries and fish culture.

Tilapia fisheries have been among the most important of the Nile since the Dark Ages. A bas relief on the Mastaba or Tomb, now in the Louvre, of Aktihetep, High Priest of the 5th Dynasty (2,500 B.C.), shows a scene of net fishing on the Nile, and the preparation of the captured fish, which are being split in half for drying in the sun (see *Figure 1*).

* By Pierre Chimits, Ing. des Eaux et Forêts, Ministère de l'agriculture, Paris.

Figure 1. A bas relief on the Mastaba or Tomb of Aktihetep, showing net fishing on [illegible] (2,500 B.C.) and tilapia being split in half for drying in the sun. (Photo by courtesy [illegible] Nationale des Monuments Historiques)

The species captured are very exactly drawn and easily recognizable : eels, mormyre, tetraodon, barbel, *Lates niloticus*, *Tilapia nilotica*, *Synodontis bentesoda*. The last species is a catfish, which has the strange habit of floating near the surface of the water, belly uppermost, as if dead or sick. It is remarkable that in this bas relief the fishes are shown in their normal positions, the only one with the belly uppermost being the *Synodontis*.

Of the 25 fish in this bas relief, four *T. nilotica* can be recognized, which indicates perhaps the abundance and importance of this species in the river fisheries of Ancient Egypt. It should also be noted that even then they knew how to dry fish.

Another scene (*Figure* 2) taken from a bas relief of the Mastaba of Kaiemankh at Giza, which also dates from the Ancient Empire (2,500 B.C.), shows a fisherman with a double harpoon capturing both a *Lates niloticus* and a *T. nilotica* — the two sacred fishes.

Figure. 2. Egyptian fisherman capturing a *Lates niloticus* and a *Tilapia niloticus* with a double harpoon. (Photo by courtesy of Caisse Nationale des Monuments Historiques)

The most interesting scene (*Figure 3*) is from a bas relief from the Tomb of Thebaine ; an Egyptian of importance is sitting in his garden, his wife just behind him, and his servants picking fruit from the trees. The master fishes with a double line, with two hooks, in an artificial pond, which is perhaps a drainable fish culture pond. The pond, with well defined edges, has in the middle a deeper central canal, used for draining. The two fish he has caught are easily recognizable by their round caudal fin as *T. nilotica*, and he is giving these to his wife so that she can unhook his catch.

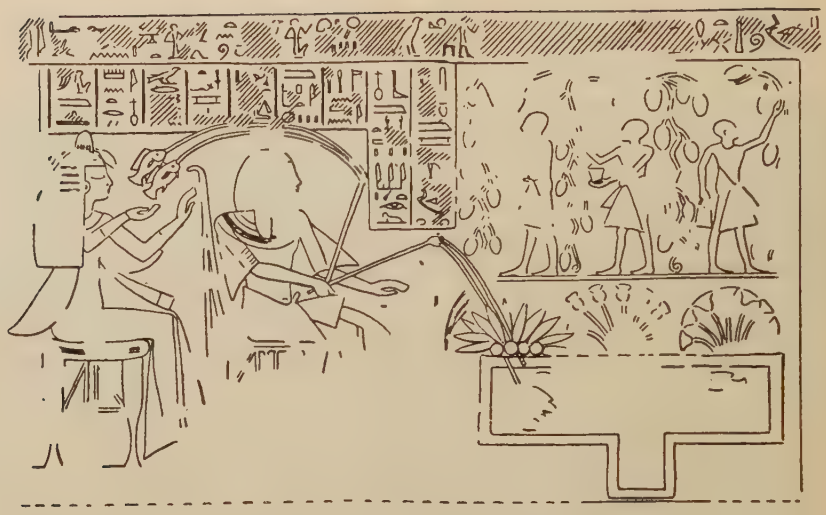

Figure 3. A bas relief from the Tomb of Thebaine (Reproduced from *Kemi*, Vol 13, 1954 Paris)

This bas relief is probably good evidence that tilapia culture in ponds was practised before 2,000 B.C., in well built, drainable ponds.

Ancient Egyptians also practised sport fishing, which had one clear advantage over that of today. In fact, in fishing parties, they were accompanied by their wives who, leaving to their husband the joys of fishing, saved them the bother of freeing the fish from the hook !

This scene, from the bas relief of a tomb, evidently has a mystical significance. But, from a fish culture point of view, it can without doubt be interpreted as a fishing scene in a pond for the culture of tilapia, just as today line fishing in the family pond, for the daily supply of tilapia, is carried out in Indonesia, in the Belgian Congo and in French Equatorial Africa, before the pond is emptied. The family pond actually in use today and recommended for the culture of tilapia, is similar to that of Ancient Egypt, with its central drainage canal and with two shallower parts on either side, for the growth of aquatic vegetation where the fish seek nourishment.

As far as is known, this is the oldest representation of a fish culture pond in the history of the world, and it is for this reason that it is reproduced in the *FAO Fisheries Bulletin.*

The first attempts at fish production in reservoirs can also be attributed to the Egyptians by referring to *Herodotus* (Book II, [149]), who wrote around 450 B.C. :

> Lake Moeris, which is in a very dry region, is fed by an artificial canal coming from the Nile ; the water flows into the Lake for six months, and back from the Lake into the Nile for another six months.
>
> With the water flowing back into the Nile, the Lake brought to the Royal Treasury, through its fisheries, one talent a day. While flowing back into the Lake, the output was only 20 mines.

Figure 4 offers yet another proof of the existence of tilapia in Ancient Egypt.

Figure 4. Two statues from Upper Egypt. Cairo Agricultural Museum, 1954. The two broad fishes with rounded tails lying horizontally across the platters are *T. nilotica.*

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FAO INTERNATIONAL FISHING GEAR CONGRESS 1957

The first FAO International Fishing Gear Congress, which took place at Curio Haus, Hamburg, Western Germany, from 7 to 12 October 1957, was attended by over 500 participants from about 40 countries. They comprised fishing skippers, fishing vessel owners, gear technologists, manufacturers of fishing gear, auxiliary equipment (winches, echo sounders and other electronic fishing aids) and synthetic fibers, biologists, and governmental fisheries administrators.

The 111 papers presented were reviewed and discussed in six technical sessions under the following headings : Materials ; Rational Design of Fishing Gear ; Rational Construction of Nets ; Operation of Fishing Gear ; Strategy and Tactics of Fishing ; Electrical Fishing.

Dr. G. Meseck, Director of Fisheries of the Federal Ministry of Food, Agriculture and Forestry, Bonn, was Honorary Chairman, and Mr. A. W. Anderson, Assistant Director, Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, Washington, D. C., was General Chairman of the Congress.

Excursions were arranged to various fishing ports in northern Germany, where the participants were able to observe different types of fishing gear, and have discussions with the local fishermen and operators.

The Congress was organized, arranged and prepared by the Technology Branch, FAO Fisheries Division. Local arrangements were generously provided by the Government of the Federal Republic of Germany, and the Senate of the Free and Hanseatic Town of Hamburg.

The great amount of technical information resulting from the Congress will be issued in book form under the title *Modern Fishing Gear of the World*, to be prepared by FAO and to be published in 1958 by *Fishing News*, J. Arthur Heighway Publications Ltd., Ludgate House, Fleet Street, London, E.C.4.

Fisheries Division Activities

Dr. D. B. Finn, Director, FAO Fisheries Division, will attend the 6th Meeting of the Permanent Commission for the International Fisheries Convention (1946), in London, in October 1957.

Biology Branch

Documentation

A *World Periodicals List for Fisheries Science* has been prepared. This *List* contains some 2,000 items, and shows for each individually the searching and abstracting of its contents that is made by nine abstracting or listing journals. The *List* has been distributed for comment to some 400 institutions engaged in fishery and related research. It is hoped to increase the information now given in it and to print it for general information in the near future.

The Branch is assisting the Editor of the *Bibliographia Oceanographica*, which now appears in English as well as in Italian, in assembling material for the 1951 and 1955 volumes. Every effort is being made to bring this bibliography up-to-date (it is hoped to issue the volumes for 1952 and 1956 during 1958 ; for 1953 and 1957 during 1959 ; for 1954 and 1958 during 1960 ; and for 1959 and 1960 in 1961). Plans are also being made to extend the coverage of the bibliography to journals not at present searched, especially in Russian and Japanese, and to improve the presentation. A Note, which appeared in Vol. X, No. 1, of this *Bulletin*, gives some further information on the bibliography.

Methods of Fishery Biology

Action is being taken as follow-up of the 1957 IPFC Meeting in Bandung and of the ICNAF/ICES/FAO Workshop on Population Dynamics and the Selectivity of Fishing Gear, Lisbon. The Branch has consulted all members of the IPFC Technical Committee I (Marine and Inland Resources) concerning plans developed at the meeting and has sent out communications on standardization of notation and other matters discussed at the Lisbon meeting of which a summary report has now been prepared.

A paper on the relations between the work of fisheries biologists and that of fishery gear technologists, written in collaboration with the Aberdeen Fisheries Laboratory, was presented to the FAO International Fishing Gear Congress 1957 (*see* p. 216).

Species and Stocks

Comments are being sought on the synopsis of data on the whale resources, prepared for distribution at the 1957 Meeting of the International Whaling Commission.

Other synopses are in course of preparation.

Marine Resources

Three contributions were prepared for the ICES/UNESCO Symposium on Methods of Measuring Basic Production in the Sea, which took place in Bergen, Norway, in September 1957. They were a general summary on methods in plankton research ; and papers on the biology of phytoplankton as basic producers, and on zooplankton as a major biotic factor in the life of phytoplankton.

A background paper has been prepared for the U.N. Conference on the Law of the Sea, planned for 1958. This is entitled " Examination of Living Resources Associated with the Sea-bed of the Continental Shelf, as defined in Article 64 with regard to the nature and degree of their physical and biological association with such sea-bed, " and is supported by a more general paper on " Conditions of the Life of Benthos in the Sea and its Quantitative Evaluation in Respect of Fisheries. "

Clifford L. Peterson (U.S.A.) has completed a twelve-month technical assistance assignment in Venezuela as fisheries biologist. He has been advising and assisting in operations to determine both the presence of stocks of clupeoids and their distribution, and to measure the abundance of the stocks.

Other technical assistance assignments continue in Panama and Indonesia, where Martin Burkenroad (U.S.A.) and T. H. Butler (Canada), respectively, are doing work connected with shrimp stocks ; in the Philippines, Dr. Karl Tiews (Germany) is assisting the Government to expand and develop its program of marine fishery reasearch ; in Brazil, Finn Devold (Norway) is helping the Government in research work on marine resources, with special reference to stocks of sardines ; and in Turkey, Dr. H. Einarsson is engaged in marine fishery research which is chiefly concerned with research on plankton.

Inland Fisheries

Wm. A. Dill, Chief, Inland Fisheries Section, visited various institutions in the U.S.A. during his home leave, and attended the meetings of the American Society of Limnology and Oceanography, Palo Alto, 25 to 29 August, and the American Fisheries Society, Las Vegas, 11 to 13 September.

While on home leave in India, Dr. T. J. Job, FAO fisheries biologist, visited many research and other institutions in Bombay, New Delhi and Calcutta, to discuss with workers the assembly of information on the resources of Indian inland waters.

D. H. Fry (U.S.A.) has taken up a technical assistance assignment in Uganda in connection with the survey of the resources of Lake George.

Other assignments continue in Guatemala and Honduras, where S. Y. Lin (China) is assisting the Governments of these countries in the development of their inland fisheries. He has also made a reconnaissance survey of the fisheries of El Salvador. Other projects, respectively under the direction of Dr. S. W. Ling (China), Dr. W. C. Beckman (U.S.A.), and of Dr. H-J. Elster (Germany), continue in Ceylon, Syria and Egypt.

Dr. F. Obregon Fernàndez (Mexico), a Fellow in inland fisheries, completed a course in Israel, Thailand, Singapore and Indonesia.

Technology Branch

Personnel

P. A. Lusyne of Belgium, formerly on the teaching staff of the Town Council Fisheries School, Ostend, on completion of an 18 month's technical assistance assignment in India as training center specialist and Associate Director of the South Pacific Fishing Training Course in Noumea, has joined the staff of the Fishing Gear Section as gear specialist. He is assisting in the preparation and supervision of technical assistance projects in fishing gear and methods, and in the preparation, writing and editing of handbooks and technical assistance reports on that subject.

Dr. J. Schärfe, formerly with the Gear Research Laboratory of the German Fisheries Research Institute, Hamburg, Western Germany, joined the Fishing Gear Section in August 1957, on a one-year fixed-term appointment. He is in charge of the equipment supply service to FAO technical assistance experts, and is helping in the general work of promoting gear research work among Member Governments, as well as in the preparations for the FAO International Fishing Gear Congress, 7 to 12 October 1957 (*see* p. 216), and the editing of the Congress Report.

Dr. W. C. Hodgson of the United Kingdom was engaged on a temporary assignment as consultant to the Fishing Gear Section for three months, July-September 1957. His duties were the editing of the technical papers to be submitted for the FAO International Fishing Gear Congress.

Fishing Boat Section

Jan-Olof Traung, Section Chief, while returning from home leave in Sweden, attended the Symposium on the Behavior of Ships in a Seaway, Wageningen, the Netherlands, from 7 to 10 September, and the 8th International Towing Tank Conference, Madrid, 13 to 23 September.

He has prepared two papers dealing with stability and propeller selection, respectively, for publication in the *Shipbuilding and Shipping Record.*

Revised plans for a 24 ft. (7.31 m.) surf boat have been despatched to Norway, where one such boat will be built for experimental purposes by Indiafondet, and to Ghana, where another will be built by FAO.

Draft specifications for a 70 ft. (21.34 m.) research vessel for the Union of South Africa have been finalized and presented to the Government. Further enquiries for advice on the design of research vessels have been received from Venezuela and Peru.

K. Rasmussen (Denmark), while traveling on home leave from India, where he is on a technical assistance assignment as naval architect, visited headquarters during June 1957. He prepared his contribution to an interim report which covers his own work and that of Paul Ziener (Norway), senior FAO naval architect in India. Mr. Ziener, on 1 July, started a training center for Indian fishing boat designers at Cochin, attended by 11 trainees from different states. The Center, which is of six month's duration, is conducted by the Central Government.

Other projects continue in Ceylon and India.

Fishing Gear Section

H. Kristjonsson, Section Chief, was General Secretary of the FAO International Fishing Gear Congress 1957 (*see* p. 216).

L. F. Farina (Italy) carried out at three-month technical assistance assignment as master fisherman in Tunisia, from June to August 1957. He conducted experimental fishing with lights, and trawling experiments.

Dr. A. Meschkat (Germany) returned from home leave to Amazonia, where he is continuing his technical assistance assignment of advising and assisting the Government in the development of the fisheries of the Amazon and its tributaries.

Other projects continue in Ceylon, Ecuador, Egypt, Haiti, India, the Philippines, and Tunisia.

Coslam Tokali (Turkey), FAO Fellow, began his tour of studies of fishing gear and methods during July 1957 with a visit to Iceland.

Fish Processing Section

Dr. W. F. Hampton, Section Chief, completed his preliminary survey of the Chilean Fish Processing Industries in July. On his way to the U.S.A. on home leave, he stopped in Lima, Peru, to discuss preparations for the Latin American Fish Processing Training Center, and in Manta, Ecuador, to discuss the future of the Fish Processing Pilot Plant there.

Dr. Hampton is Associate Director of the Fish Processing Training Course, which will run from 21 October to 14 December 1957, in Lima and Callao, Peru, and be attended by trainees from countries of Latin America.

Rolv Vesterhus (Norway) took up a 12-month technical assistance assignment in July 1957, in Turkey, as fishery technologist. He is stationed at Istanbul, where he is advising and assisting the Government in the establishment of a fish preservation research and control laboratory, in training the personnel and in preparing and initiating a program of research and quality control, especially in the fields of fish freezing, cold storage, transport and fish canning.

Gudmund Sand (Norway), arrived at headquarters in June 1957 on home leave from Thailand, after 18 months there on a technical assistance assignment. Before returning to Thailand in September, he prepared an interim report on his work as fish processing specialist.

Other projects continue in Brazil and India.

Economics and Statistics Branch

Yearbook

The *FAO Yearbook of Fishery Statistics* 1955-56, Vol. VI, has now been issued. This new edition presents a series on catches, landings (by weight and value), disposition of catches, production of preserved and processed commodities, fishing craft, and whaling, in continuation of those contained in the earlier volumes. Details of catch and landings by groups of species which formerly could be given for certain countries only, are now shown for the world as a whole. A more complete series of official figures for the U.S.S.R. has been obtained and, in addition, a new table gives fishing craft statistics for that country.

The *Yearbook* is available from FAO, Rome, or from FAO Sales Agents, price U.S.$4.00 or £1.

Official Visits

En route to North America in August 1957, Mr. F.E. Popper, Branch Chief, had discussions with officers of the International Economic Association in London regarding the printing of the report of the Round Table on Fisheries Economics, held in FAO Headquarters, Rome, in September 1956. This report, which will contain the papers submitted to the meeting, will shortly be available from FAO.

In Reykjavik, Mr. Popper talked with Mr. D. Olafsson, President of the Iceland Fisheries Association and representatives of various industrial organizations regarding the two forthcoming

FAO technical meetings, one on Costs and Earnings in Fishing Enterprises, to take place in the autumn of 1958, probably in London, and the other on Fishery Co-operatives, to be held, possibly in Gothenburg, in 1959.

In New York, Mr. Popper discussed with the U.N. Statistical Office data to be incorporated in a paper on the economic importance of the fishing industry in various countries, which the Branch is preparing for submission to the U.N. Conference on the Law of the Sea, to be held in Geneva, February/March 1958. He also had discussions with officials of the Rockefeller and Ford Foundations, particularly in connection with an FAO study of middlemen and co-operatives in the Far East, and with the Atlantic States American Fisheries Commission regarding the Technical Meeting on Costs and Earnings.

In Ottawa, Canada, Mr. Popper had discussions with the Department of Fisheries and the Bureau of Statistics, concerning the project for standardization of statistical reporting to international organizations in the North Atlantic area; with officers of the Department of Agriculture, Department of Fisheries and the Co-operative Union of Canada, concerning the preparation of papers for the Technical Meeting on Fishermen's Co-operatives; and with the Fisheries Council of Canada regarding the Technical Meeting on Costs and Earnings. He also discussed plans for exchange of information on consumer education projects.

Arrangements are being made for Mr. F.J. Rashley of the Dominion Bureau of Statistics, in collaboration with Mr. J.B. Rutherford of the Department of Fisheries, to undertake, on behalf of FAO, a survey of statistical reporting in the North Atlantic area. Mr. Louis Bérubé of the School of Fisheries of Laval University will prepare a background paper on the development of fishermen's co-operatives in North America and will be assisted by an advisory group, with participation from all parts of Canada and the U.S.A.

In Washington, Mr. Popper had extensive talks with officers of the Bureau of Commercial Fisheries on those subjects previously discussed in Ottawa. He also had meetings with the National Fisheries Institute and the National Canners Association.

In Boston, Gloucester, and Point Judith, meetings were held with representatives of the Bureau of Commercial Fisheries, industrial organizations and fishermen's co-operatives.

Mr. Popper returned to Headquarters at the end of September.

Y. Miyake, fisheries economist, during July 1957, held consultations with government authorities and various institutions and organizations in Geneva, London, Bergen, Oslo, Stockholm, Gothenburg, and Copenhagen, with regard to two forthcoming technical meetings planned by FAO.

K. Ruud, fisheries economist, returning from home leave in Norway, visited Oslo, Gothenburg, Copenhagen, Bremerhaven, the Hague, IJmuiden, and Amsterdam, for discussions with government authorities and institutions regarding fish consumer education,

and to ascertain interest in a systematic international exchange of information and materials used in connection with the promotion of fish consumption. At the ports he visited the fish wholesale markets and collected information to be published in a projected FAO document on fish markets and terminals.

Statistical Methods and Surveys

K.V.R. Sastry (India), fisheries statistician, who, in 1956, was working in Egypt, assisting the Government in improving the collection of fisheries statistics through the employment of sampling methods, returned there in June 1957 to resume his long-term appointment.

Fish Marketing

Dr. J.A. Crutchfield (U.S.A.) has taken up a 12-month assignment in Uganda as fish marketing specialist. He is making a survey of the fish marketing situation, studying in particular the problems of disposal of fish from the lakes of Western Uganda, and is advising the Government on measures for increasing the efficiency of marketing operations.

G.C. Salmon (France) has completed a one-year assignment in Trinidad with the Caribbean Commission. He has been engaged in advising the Commission on the development of local fish marketing, including preservation, government fishery administration, and assessing the need for further technical assistance in these fields.

Two fellowship holders from Japan, M. Kato and T. Homma, have started their courses in Europe on food marketing and fish trading.

New GFCM Publication

A second publication in the series *Studies and Reviews*, issued by the General Fisheries Council for the Mediterranean, is now available. This one, No. 2, is entitled *Mediterranean Trawling - Preliminary Observations in the Study of Italian Trawl Nets.*

On the occasion of its 4th meeting (Istanbul, September 1956), the GFCM (Production Committee) discussed a working paper on "Mediterranean Trawling, a Proposed Rational Study with a View to Improved Efficiency." This paper was prepared by H. Kristjonsson, Chief, Fishing Gear Section, Technology Branch, FAO Fisheries Division.

The paper stressed the need for improving the efficiency of the Mediterranean trawl through a rational study and the Production Committee, recognizing the importance of this question, decided to adopt the working plan proposed by Mr. Kristjonsson.

Thanks to the assistance of FAO and to the help of the Italian Government, it was possible to implement some of the points

included in this plan of work. However, due to lack of means it has not been possible to date to carry out the entire plan.

The Executive Committee of the GFCM thought that it would be of interest for its members if the results already obtained after the first studies could be published. It was also thought useful at the same time to publish the text of the working paper on the basis of which the preliminary experiments were carried out.

The Executive Committee hopes that with the help of the member countries, and the assistance of FAO, it will be possible to resume these studies, and to carry out the entire working program adopted by the GFCM in this field.

Studies and Reviews No. 2 is available free of charge, on request to the Secretary, GFCM, Rome, Italy.

New Publications

TRESSLER, DONALD K. and EVERS, CLIFFORD F. *The Freezing* 1957 *Preservation of Foods.* Vols. I and II. 3rd ed. Avi Publishing Company Inc., N. Compo Road, Westport, Conn., U.S.A. In English. Price : Vol. I (1,236 pp., illus., tables) U.S.$18.00, Vol. II (574 pp., illus., tables) U.S. $10.00.

A completely revised and greatly augmented edition in two volumes of the 1947 publication.

Vol. I comprises 31 chapters. Besides considering such problems of general interest as freeze-drying, microbiology of frozen foods, transportation, marketing, sanitation, quality control and standards, two chapters deal exclusively with fish : " The Preparation and Freezing of Fish, " and " The Preparation and Freezing of Shellfish. "

Vol. II is an entirely new book, complete in itself, and contains information on the production, marketing and use of frozen precooked foods and desserts, baked goods and confections. Two of the 24 chapters deal with precooked fish and fish dishes, and prepared and precooked shellfish.

PICKFORD, GRACE E. and ATZ, JAMES W. *The Physiology of the* 1957 *Pituitary Gland of Fishes.* Published by the New York Zoological Society. Orders to be addressed to : Publications Office, New York Zoological Park, New York 60, *xxiii* + 613 pp., 25 text-tables, 3 text-figures, 54 tables, index. In English. Price : U.S. $ 6.00.

A review of the extensive and widely dispersed literature on physiology of the pituitary gland of fishes. The nature of the pi-

tuitary gland hormones and their sites of origin are discussed. The regulation of the target organs and their functions is reviewed in relation to the biology of the organism as a whole, and a comparison is made with the knowledge of pituitary physiology in higher vertebrates.

Methods of treating fishes with gonadotropic hormones in order to induce reproduction in captivity are described in detail, including the extensive fish cultural work that has been carried out in Brazil, Japan and the U.S.S.R.

A vast bibliography on the subject is given.

KRAMP, P. L. Hydromedusae from the Discovery Collections. 1957 *Discovery Reports*, Vol. XXIX, pp. 1-128. Cambridge University Press, 200 Euston Road, London, N. W. 1. In English. Price : £3.3*s*.0*d*.

REES WILLIAM J. and WHITE, ERNEST. New Observations on the 1957 Aberrant-Medusa *Tetraplatia volitans* Busch. *Ibid.*, pp. 129-40. In English. Price : 8*s*.6*d*.

KUFFERATH, HUBERT. Algues et protistes du fleuve Congo dans 1956 le bas Congo et de son estuaire. Parts 1 and 2. *Expédition océanographique belge dans les eaux côtières africaines sud* (1948-1949). Vol. V, No. 1. Institut royal des sciences naturelles de Belgique, Brussels. 75 pp., illus., bibl. In French.

A study of the algae and protista collected in the Congo river and at its mouth, in waters of different salinity gradients. Part 1 lists the species at the Island of Mateba ; Part 2 gives the species collected around and in Banana Creek.

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Pesca (Resursos y possibilidades nacionales). Vol. 1, No. 1, September 1957. Monthly. San Mateo 19, Apartado 28,139, Azcapotzalco (16). Mexico, D.F. M.$1.00.

EINSELE, W. Flussbiologie, Kraftwerke und Fischerei. *Schriften des österreichischen Fischereiverbandes*, Heft 1. Obtainable *Österreichs Fischerei*, Scharfling-am-Mondsee 700, Austria. Sch. 10.

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